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Contracting on a Percentage or Like Basis.

A large part of the ordinary lump-sum contracting business has always been done on a more or less uncertain basis. It is only within a comparatively few years that the preliminary examinations on which specifications for engineering work are based and which determine largely the conditions governing a bidder's price have been carried even approximately to the extent necessary to eliminate the larger doubts of ultimate cost. Even at the present time the comparatively full examinations usually made for the guidance of bidders are not sufficient in many cases to free the work from all resemblance to a gamble. Indeed, it may sometimes be impossible in large works to disclose all material working conditions short of actual construction. Alert experienced contractors appreciate fully the business significance of such features of construction. It is absolutely essential to the success of their business that their prices should be sufficient to cover not only the costs which they can estimate completely, but also those exigencies of expense, many of them large, which, while they cannot accurately outline them, they know well enough are sure to occur. More than this, inasmuch as it is impossible from the nature of things to fix quantitatively such hazards of contracting, they are bound to make their tenders high enough to cover both reasonable and unreasonable conditions. Many a contractor has come to grief by not observing these simple business considerations.

The lump-sum contracting method has many advantages. While the owner may have to pay high for some portions of his work he at least knows the limit of his costs, i. e., he knows the worst at the outset, and if it is too much for his resources he may at least decline to undertake the project. As methods of examination, however, have been developed by engineers and their costs much reduced, contracting hazards have been correspondingly diminished. This might and does indicate that the lump-sum procedure is freed of much of the uncertainty which attached to it in older engineering works. But this is not the whole of the story. The increase in magnitude of engineering projects has enhanced some serious difficulties of construction to an extent which has at least kept pace with the means of determining their exact character and amount, if indeed in some respects they have not outstripped those means. At any rate, in the greater engineering works undertaken at the present time there are still correspondingly great uncertainties, notwithstanding the much improved procedures for extending and completing preliminary examinations. Under these conditions it becomes a serious question just how far the contractor must be forced to assume the hazards of his work of construction and to what extent he must correspondingly increase his tender prices to cover them, and whether it is not best to remodel his part of the work so as to reduce it more nearly to the character of a stable business.

It is well known that a considerable number of contractors of established reputation who have developed after years of experience organizations of great efficiency and whose business integrity has been established beyond doubt, are constantly doing building and other structural work on a percentage or similar basis, thus eliminating the uncertainties of lump-sum bidding. This is a change which obviously will find general acceptance very slowly. Human nature is, on the whole, about the same wherever it is found, and the continual evolution of efficiency needs the spur of self-interest. A simple, straight-out percentage on the cost of the work will scarcely be found satisfactory in the long run, although there are some special works or parts of works which can be handled in that way only. If compensation is to be made either on a percentage of the cost of construction or as a fixed sum, it obviously must be so established or conditioned that it is to the interest of the contractor to complete his work as economically and expeditiously as possible. This is no reflection upon any contractor acting wholly as such or more or less as a kind of agent for the owner; it is simply recognizing one of the fundamental principles of human action as deduced from the whole history of experience.

Probably the most marked instance in this class of contracting is that of the proposed construction of the Panama Canal, which received editorial comment in the preceding issue of this journal. The conditions of that work are peculiar. Probably the United States Government is in less favorable position to enter markets for the purchase of its supplies than the contractor who usually makes his own purchases. At the same time it is probably best to control most effectively the quality of the immense amount of material to be used in that work, even at the price of some additional cost. Again, it is imperative that the government should control absolutely on the Isthmus conditions like sanitation, cost of living of the employees and other similar features which are frequently under the contractor's control with at most some general supervision. It would be extremely unwise for the United States Government to relinquish control of all the larger essential features or conditions of construction of the Panama Canal, but it would probably be far more unwise for the Commission to attempt to do the work of construction by its own forces. There would certainly be great inefficiency, at least in some important portions of the work, and the costs would be greatly swelled by incapability to secure the requisite organization for this great work. There will probably be some question whether safe-guarding the percentage method and protecting against excessive costs have been carried far enough in the contemplated contract form, or whether the prescribed means for accomplishing that end will prove sufficiently effective, but the general plan is undoubtedly an excellent one.

While there are some large differences between the contracting of a great national commission and that of private or semi-private corporations, yet there are certain general principles which are applicable to both. It is undoubtedly a wise business policy to free the execution of contracts from those undimensioned hazards which lead to gambling features. At the same time it is imperative that the owner should be assured of at least a close approximation to the cost of the work and protected against any unreasonable or excessive outlay. The unqualified percentage or fixed sum system certainly does not accomplish these ends, but there seems to be no valid reason why safe-guarding conditions which both stimulate the interest of the contractor and conserve those of the owner cannot be determined and incorporated into a contract agreement. This is a portion of the contracting field which has not yet been sufficiently exploited.

The American Coal-Tar Industry.

The United States Census for 1900 gives the amount of capital invested in the manufacture of chemicals and allied products as nearly $500,000,000, and states that the value of the products in this group has increased three-fold in the ten years since 1890, so our progress in this line, speaking generally, may be said to be encouraging. But the report also calls attention to the fact that in the particular line of coal-tar chemical manufacture, we have lagged behind our transatlantic brethren. In the year 1905 we imported over seven million dollars worth of alizarine, aniline salts, coal-tar colors, dyes and other coal-tar chemical products, instead of making them for ourselves from the raw material plentifully at our hands. It seems fitting, therefore, that on the occasion of the visit to this country of Sir William Henry Perkin, to take part in the celebration of the fiftieth anniversary of his discovery of mauve, on which the development of the coal-tar chemical and color industry is based, some word should be said as to the cause of this, and also to call attention to the fact that, in spite of our conservatism in this direction, we have a strong and well-developed coal-tar industry that, within its own lines, will compare favorably with the similar ones existing in the older countries.

In the conquering of the wilderness and the development of a new country, the pioneer and farmer are followed by the engineer, with his railroads, highways and bridges, and the builder of houses, stores and factories; with them come commerce and the development of the industrial arts. To them, therefore, the coal-tar industry of the United States has first offered its wares, and to their needs its products have been studiously adapted. The making of saturated felt and prepared roofing papers; the simple distillation of tar, yielding light and heavy oils, the latter used principally in the creosoting of timber, together with soft pitch for paving, roofing, waterproofing and preservative coatings; the compounding of coal-tar paints and varnishes, and, more recently, the spreading of prepared tar on roads for preserving them and laying the dust; these are the uses to which the great bulk of the tar produced in America has been put. The manufacturing processes involved in the production of these articles are, relatively speaking, simple, and the problems are, for the most part, those of handling large quantities at low cost. As our towns grow into cities, their organization becomes more complex, their needs and their activities become more varied, and this change is recorded in the progress of their industries. The industrial history of this and of other countries as well, will show that those classed as chemical industries are usually the later to be established. They demand for their profitable conduction the refined skill and scientific knowledge that comes to men, as to nations, only with riper years.

The coal-gas industry, which was the original source of the coal-tar supply, had its beginning in England and Europe in the early years of the nineteenth century, although the Earl of Dundonald patented a method of obtaining tar in coke making, about 1776. The first city to be lighted with coal gas in the United States was Baltimore, in 1821. England, therefore, had some twenty years the start of us in the matter of a native tar supply, in addition to the immense advantage of a denser population, as favoring the extension of the gas industry. We in the United States can still recall the time when it was necessary to admonish the visitor from the rural districts not to "blow out the gas." The supply of tar, however, no longer depends upon the coal-gas plants alone. The introduction of the by-product coke oven in Germany and the United States, and, to a lesser extent, in England, has brought a large additional supply of tar on the market, though not yet exceeding the amount of tar derived from the gas works alone, in this country at least. The production of tar in the year 1904 from gas works and by-product coke ovens in the United States was 70,000,000 gal. Of this 60 per cent. was from the gas works and 40 per cent. from the coke ovens. If we go back to 1895, which is before the tar from coke ovens had become an important factor, and allow for the increase of production in 1905, it is conservative to say that the country's tar output has been increased three and one-half times in the last ten years. This corresponds to an annual increase of about 13 per cent. The fact that the industry has taken care of such an annual increment of raw material, practically thrown on its hands for so long a time, and without having to resort to the lower priced products, as for instance, fuel pitch for briquettes, into which so large a proportion of the English and Continental tar is made, is convincing evidence that the demand for the American-made coal-tar products is genuine and permanent. Furthermore, it shows that the articles produced are well suited to existing architectural and engineering needs. Such results do not come about fortuitously, but demand keen and patient study.

Until the advent of the by-product coke oven, the tar supply of the country was far short of what it might readily be expected to absorb. This condition was due, in part to the widely extended use of carburetted water gas in place of coal gas. This relative scarcity of tar is shown by the importation of tar and pitch in 1895, amounting to 116,000 bbl. In the year 1905 this had fallen to some 46,000 bbl., or less than half, instead of an increase, which might have been expected under ordinary conditions. It is, therefore, not to be wondered at that the American industry, in the face of this enormous influx of crude tar, has hesitated to attempt the organization of an industry so complicated as the making of drugs and dyes. The natural tendency is to seek profit by the shortest and simplest methods, so long as they can be made remunerative. The coal tar chemicals, furthermore, absorb but relatively small amounts of tar, when compared with the cruder uses. The benzol, which in Germany is so largely extracted from the coke oven gas, for the use of the chemical works, is usually needed in the gas in this country, where it is used for illuminating purposes, especially since the legal candle-power required in American cities is apt to be higher than that required abroad. In neither England nor Germany, moreover, has so much progress been made in the use of coke oven gas for ordinary city distribution, as in this country.

Whether this country will eventually take up the manufacture of aniline colors and chemicals, it is impossible to say. Reasons for not doing so have been advanced, as, for example, the alleged scarcity of competent chemists willing to work for the moderate recompense paid abroad, and the strong intrenchment of the industry in the hands of German companies. Some refined benzol and toluol, also oil of myrbane and naphthalene in different forms, are made at Philadelphia; some alizarine and aniline products are made elsewhere; these beginnings may be the foundation of larger things. Whether the next decade will still see us outsiders and onlookers in this branch of manufacturing enterprise, we must leave to the decision of time.

The Interurban Electric Railway.

The convention of the American Street and Interurban Railway Association at Columbus this week was a significant demonstration of the importance of the interurban electric railway. This was natural, for Ohio and Indiana together afford more examples of such roads than any other section of the country, although they are also well served by steam roads. The visitor to the convention could not help but be impressed by the fact that the interurban aspect of electric traction is to-day the most interesting in the whole field, for its development is calling for assistance from both the teachings of the city railway operation and the practice of steam railways. So long as a horse or mule was the unit of motive power, the street railway was merely an urban convenience, but when electricity was introduced and higher speeds became possible the development of suburbs by street railways followed very quickly. This development was so natural as to attract little attention, but now that the electric car has dropped the little 10-h.-p. motors with which it started and taken on four that have a collective rating of anywhere from 200 to 400 h.-p., so that it can speed across country on schedules calling for 20 to 40 miles an hour, it has achieved a prominence in the transportation field which makes it the cynosure of all eyes. While this interurban electric business is not particularly novel technically, save in the opportunity it affords for using higher line voltage, it is working a change in railway affairs the magnitude of which cannot now be clearly estimated.

When the interurban electric road first began its career it was little more than a glorified street railway, having larger cars with more powerful motors and a more brilliant headlight. It was merely a city line running across country, stopping wherever a passenger desired and running on a regular hourly schedule or something of that sort. Attention was concentrated mainly on the traffic between the connected cities. Now the whole system is being changed. The managers of these lines have awakened to the fact that while the operators of steam lines, particularly branch lines, have lost a golden opportunity in failing to introduce electric traction, nevertheless they knew a lot about the actual handling of traffic when it was obtained. Consequently the cars of the interurban electric roads no longer stop except at regular stations, and by this means are able to run at a speed and in accordance with a schedule impracticable when they are halted wherever a passenger desires. Moreover, the schedule of trips on regular intervals has been abandoned in favor of one made up to conform with the actual demands of the traffic. There are certain times of the day when the passenger traffic is heaviest, and cars are run more frequently then. There are other times on some roads when express and freight is ready for shipment, and cars have to be provided for it. There are other times when it pays to run cars on an express schedule, and this again interferes with a time table made up on the basis of regular intervals between cars. In consequence of the recognition of all these factors in the operation of a successful interurban service, electric roads are running across country to-day which are distinguishable from steam roads in no essential feature save the different tractive system and the entrance of the cars into the city over the streets.

This evolution of interurban electric cars has now reached a point where it is necessary for city engineers to watch further progress with a greater degree of attention than before. The largest of the cars in this service are of great weight and their operation over ordinary street track is not at all easy in most cities, owing to the deeper and thicker flanges used on their wheels. There are places where the track is being seriously injured on this account, and in those places it is generally found that the street railway officials are endeavoring to secure the introduction of T rails. This was brought up recently at Hartford, for example, where the city engineer had to make a strong fight in order to keep such track off some of the streets over which it was proposed to run interurban cars. This situation brings up a subject which has not yet been fought out in any city, but is nevertheless sure to come up soon, the extent to which it is desirable for such heavy cars to run over city streets. A street is occupied by railway tracks by municipal permission and when the tracks cause inconvenience for any reason they will have to be modified sooner or later. If the track adapted for interurban cars must be one which makes it impracticable to maintain a good pavement along it, then such a track should not be laid on a leading street. The heavy interurban cars may run into the city on unimportant streets, or else stop at transfer points, and receive their passengers there from the regular city cars. This solution of the problem does not cause any serious inconvenience to the passengers, if suitable waiting rooms are provided, as is shown by experience in transferring people in many cities. It enables the schedule of the interurban service to be maintained more closely and keeps these cars in a service better adapted for them than running through the streets of a city at slow speed. It also enables the track system on the city streets to be one which is not destructive to pavements. The engineers of street railways now find that their tracks are going to pieces rapidly where they are used by large interurban cars with heavy wheels, and just what to do to prevent this is causing them considerable study. Special track work is costly, and so are wheels, and the use of heavy and light cars on the same track is proving very expensive. It would, therefore, seem that the practice of running interurban cars promiscuously over city streets might be stopped with advantage to everybody. If this is done and the interurban cars enter a regular terminal over tracks which do not run down the leading streets, as there is now a tendency, the difference between electric and steam roads dwindles down to insignificance, except as to motive power. With both classes of roads on private right-of-way, with regular stations along their lines, there is no essential difference between them, save as the service of the electric system is likly to be better on account of frequent single cars rather than infrequent trains.

A Gigantic Electric Power Equipment.

In the proposed equipment of the great new plant of the United States Steel Corporation at Gary, Ind., now under construction, there will be noted what perhaps must be regarded as the most striking electric motor installation in the world. The Gary plant, as mentioned in the Current News Supplement of this week, has a capacity of two and a half million tons of steel annually, and practically all the machinery will be driven electrically, including the main rolls, which have in all former plants been engine-driven. The problem of driving such rolls is a peculiarly formidable one on account of the need of taking up quickly an enormous load. It is probably the severest work upon which a motor could possibly be put. In this case three of the motors to be used are of 6,000 h.-p. normal rating, with an overload capacity of 50 per cent. for one hour, so that the rating under use will approximate 9,000 h.-p. These huge machines are of the three-phase induction type, which is peculiarly adapted for dealing with sudden overloads, and it is very doubtful whether a direct-current equipment would have been capable of meeting the requirements. The induction motor, quite apart from the absence of a commutator and the attendant probability of serious sparking under extreme conditions, has the unique merit of having its armature voltage quite independent of the voltage of the supply. This means that whatever voltage is desirable for the transmission of power to the motor can be freely employed while the induced armature voltage can be made anything that will best meet the conditions of torque and control. If necessary the armature can be made almost as solid as a flywheel, and can be freely designed for the severest mechanical strains. Hence it is practicable to build induction motors for uses which would be well-nigh impossible for motors using direct current.

The regulation of speed in induction motors is accomplished by inserting resistance in the armature circuit. Contrary to the common belief, speed regulation by this means is very easy and is accomplished upon precisely the same terms as the regulation of a common street railway motor by cutting down the applied voltage through a rheostat. It is not efficient by reason of energy wasted in the rheostat, but in the operative sense it is entirely effective. The motors for the rolls in the case under consideration must be capable of enormous torque and of very prompt reversal, as well as speed regulation, and the whole control is accomplished indirectly through a device on the principle of the street-car control, by which the motor can be started, stopped, reversed and adjusted in speed. Of course to take up the tremendous shock of starting up the rolls on heavy work, the aid of a flywheel is desirable, and each roll motor is coupled to a massive one and so connected, moreover, that it does the maximum amount of good. A relay carries the main motor current, and when this rises abnormally, as it does when the rolls begin their work, a small resistance is cut into the armature circuit, thus lowering the normal speed of the motor and throwing the flywheel energy into action during the slight drop in speed. Then, as the load falls off the resistance automatically comes out and the motor speeds up the flywheel ready for the next attack. Big as the innovation is, there is no sort of doubt that it will be successful since induction motors are admirably suited for just the hard work they must meet in such a case as this. They have gradually come to be appreciated in the past decade, so that they are now often preferred to any direct-current motors on their merits, and have been used in many isolated plants where the use of alternating current was adopted for the sake of the motors. A good induction motor is more nearly "fool proof" than anything else in the line of dynamo-electric machinery. It is very difficult to burn one out or damage it by overload, and it will run in dust and dampness with far less likelihood of trouble than any other sort of motor. The Gary plant is a deserved tribute to its good qualities and should make a record that will go far toward establishing the electric drive as a regular feature of rolling mill practice in future installations.

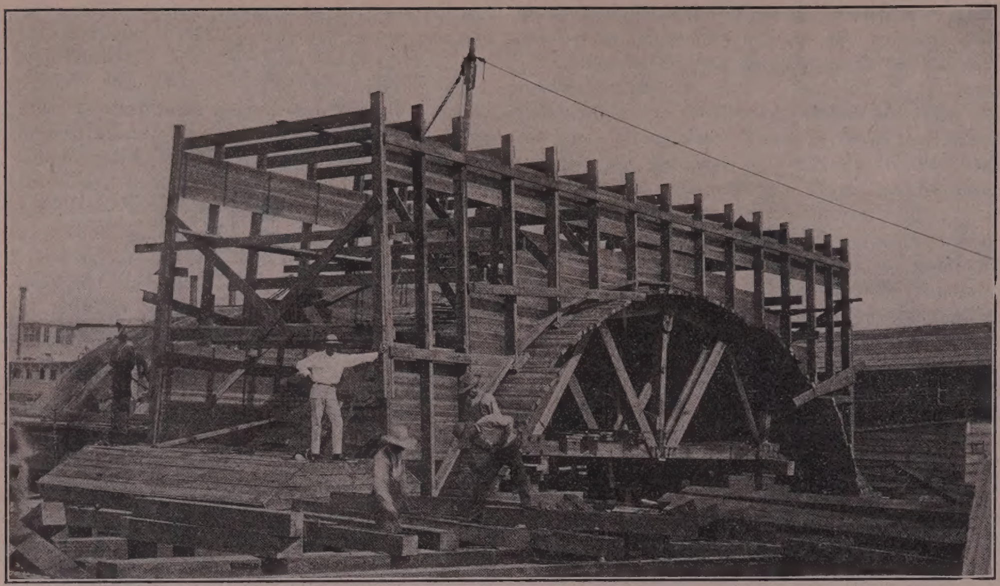
The Mechanical Lessons of the Long Island Automobile Race.

Most of the newspaper comments on the Long Island automobile race early this month read like extracts from a joke book. Anybody acquainted with the management of a high-power car and also with the driving of a high-spirited trotting horse knows that, so far as danger is concerned, racing with one is on a par with racing with the other, provided the course is kept clear in each case. The great danger on the Long Island course came from the thousands of reckless spectators who risked their own lives and those of the racers by crowding over the road and by massing themselves at the turns where the cars were most likely to escape from control. By good luck the casualties of the occasion were few, but this was not on account of any hesitation on the part of the spectators to tempt injury and death in the most brainless fashion. Fortunately the impracticability of more such contests has now been recognized, except possibly on private courses where the track can be properly safeguarded. On a par with the stories about the driving of these racing cars are the funny comparisons between the speeds attained and those regularly made by fast express trains. These cars were racing machines, stripped down to the last nut and bolt in order to save weight; they were, with a few exceptions, designed simply to get over the ground as fast as possible under conditions that made it impossible to get any pleasure from riding in them. They all suffered various troubles which interrupted their running in a manner that very rarely occurs on an express train, and to compare their record with that of such trains is as foolish as an attempt to compare, say, ice cream and cheese.

There are, however, some instructive mechanical lessons to be learned from the race. Seventeen cars started and thirteen were running when the contest was stopped. The five cars allowed to finish completed the 297.1 miles within 15 minutes of each other, their average speed having been 58.01 to 61.43 miles per hour. These facts prove that the gasoline engine is a reliable prime-mover under very difficult working conditions, and that a carefully designed and built car is a fine piece of machinery. The broken connecting rod of one car was the mechanical feature of the race that was most important; in fact it should go far to cheer up those motorists who have had like trouble. The connecting rod in question unquestionably was designed and manufactured with great care, and the fact that some minor part of it broke should not be laid up against automobile design in general any more than the occasional broken crank shaft of a steamship is considered a reflection on all marine engineering. The only other serious mechanical trouble was to the steering gear of one of the cars. This gear had been recently drilled with a lot of holes in order to bring the car down to the allowed racing weight, and as the fracture occurred at one of these holes, this break teaches nothing but the foolishness of tampering with the strength of a fine piece of high-power machinery. The great source of trouble was with tires, as is the case in ordinary touring. The tire is to-day the least satisfactory part of a car, and the magnificent running of the Locomobile car, which made the fastest lap of the race, was rendered hopeless by the necessity of wasting about fifty minutes on account of tire troubles.

Although from a sporting point of view the result of the race was not gratifying to Americans, nevertheless the appearance of the American cars when time was called is satisfactory proof of their good quality as regular touring machines. The Locomobile met defeat because of tire trouble and the Thomas car was seriously handicapped for the same reason. The 50-h.-p Christie car and the 60-h.-p. Haynes car were not racing machines in any sense, and were naturally outclassed by competitors of double their power, while the air-cooled Frayer-Miller car was such an untried type that it really had no business in an international race. There was nothing about the work of the American cars which needs any apology from a mechanical point of view, and although our machines did not win a place the fact that four out of the five were running well when time was called, and the one out of commission retired only on account of a broken fan, speaks well for their mechanical construction. As a matter of fact most of our American cars are good reliable machines for regular automobile work, and some of them are excellent examples of mechanical construction. Not only are they good in themselves, but the interchangeable system of their manufacture enables them to be turned out at a low price, the shop cost of one of the most expensive being under a thousand dollars. At the present time the excessive cost of marketing the cars keeps up their selling price, but just as soon as they are sold at establishments which do not pay the same rentals as fashionable jewelry shops, they will be priced more reasonably. There are, to be sure, some widely advertised cars which are dangerous to anybody riding in them on account of the poor material and workmanship in them, but these exceptions are so few and so notorious that they do not affect the general standing of the industry.

The Key West Extension of the Florida East Coast Ry. is one of the most unique undertakings now in course of execution, as is evident from the description on the following page of the reinforced concrete arches, keeping the track high above the waves, which are a feature of the line. It starts at Miami and will run to Key West over a route 154 miles long, of which 74 miles will be on land, 25 miles on swamps and the remainder over water or on the long line of islands that make up the Florida Keys. There will be a temporary harbor constructed at Bahia Honda, to handle the Cuban traffic for which the road is intended, until the rails can reach Key West and facilities be provided there for the enormous ferry-boats it is proposed to run to Havana, 100 miles distant.



Arch Center and Spandrel Wall Forms Under Construction.

CONCRETE VIADUCTS ON THE KEY WEST EXTENSION OF THE FLORIDA EAST COAST RY.

By George P. Carver.

The concrete construction of the Key West Extension of the Florida East Coast Ry. consists of about 500 reinforced-concrete segmental and semi-circular arches of from 45 to 60 ft. span and has an entire length of about six miles. This distance is divided into four parts, there being a viaduct two miles in length between Long and Conch Keys, known as the Long Key-Conch Key viaduct; a viaduct between Knights Key and Pigeon Key being about 7,800 ft. long and known as Knights Key Channel viaduct; a third structure known as the Moser Channel viaduct, just south of Pigeon Key, is about 7,300 ft. long, and the fourth being known as the Bahia Honda Harbor viaduct, is about 4,950 ft. long, and is composed of 60-ft. arches. Approximately the following quantities of material will be required in the construction of these viaducts: 300,000 barrels of cement, 225,000 cu. yd. of sand, 200,000 cu. yd. of crushed stone and gravel, and about 5,000 tons of steel reinforcing bars. The piers for these viaducts are constructed in from 6 to 30 ft. of water on very hard, but porous lime rock and coral, which is overlaid with sand.

The accompanying cross section of through the center of one of the arches shows the typical design that has been employed. The arches will be 15 ft. wide at the crown, allowing sufficient width for a single standard-gauge railroad track. The sides will be battered at the rate of 1 in. to the foot of height. The rails of the track carried by the structure will be about 31 ft. above mean low water. The piers will be about 21 ft. long and 7 to 12 ft. in width. Every fifth pier, being considerably wider than the other piers, will be an abutment. The arch rings will be 2 ft. thick at the crown and about 4.5 ft. thick at the top of the pier. The spandrel walls are about 18 in. thick at the top, 3 ft. above the crown of the arch and batter down 1 in. in 12 in. on the outside and 1½ in. in 12 in. on the inside, making the width about 5.5 ft. on top of the pier. There are about nine tons of ⅝ and ¾-in. twisted steel bars in each complete arch.

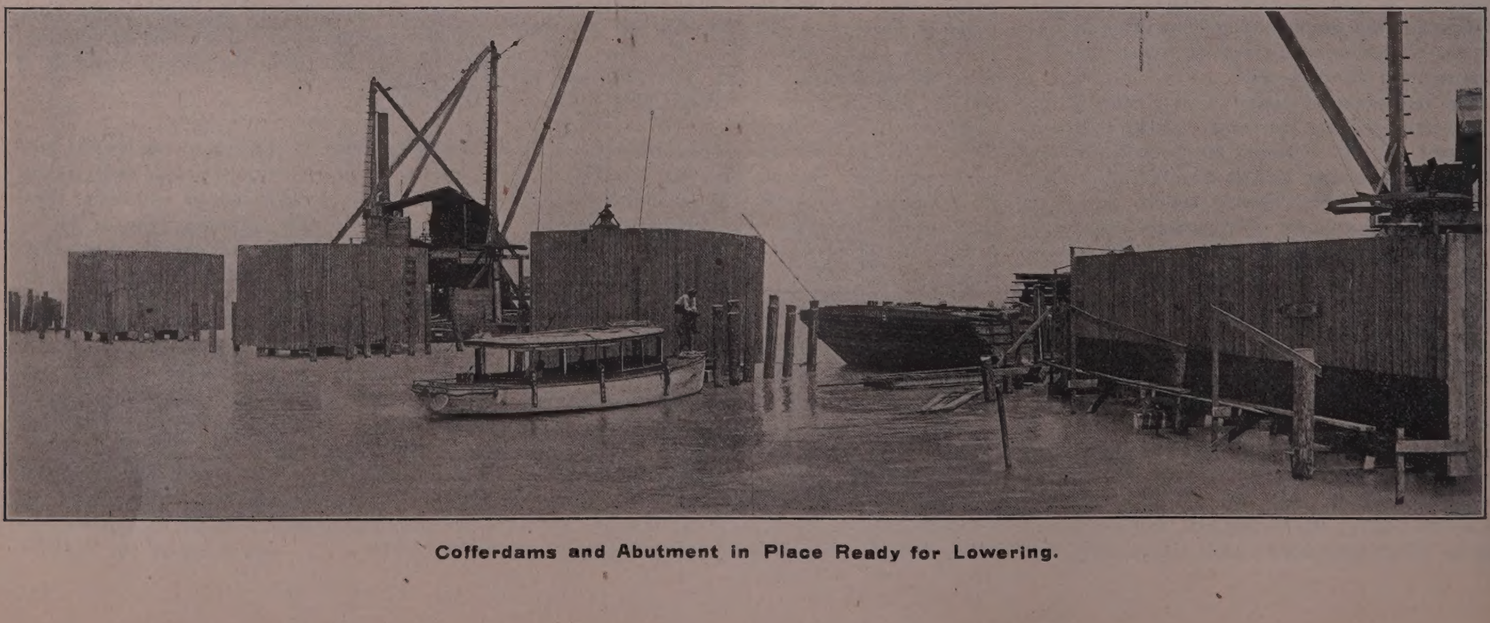
At the present time there are three large quarter boats in the field fitted to accommodate about 150 men each, including engineers and firemen. In addition to this there are two pile drivers and three work barges. Accurate surveys have been made and piles are being driven in the abutment and pier locations, cofferdams are being placed and construction is well under way. There will be about eight complete construction plants put in the field, each comprising a unit. The first plants on the work are used on pier work, and when that work has progressed sufficiently far to allow the concrete in the first piers placed to set, the next plant arriving takes up the arch ring work and carries that work on until the concrete in the first arch rings has set, and the last plants to arrive will commence the spandrel wall work. On the completion of the pier work on the first viaduct, the plants will probably be towed to the location of the next viaduct and commence pier work at that point.

Each working barge is 40 x 70 ft. in plan and 6 ft. 2 in. deep. It is equipped with a large-sized concrete mixer and engine, a 90-h.-p. locomotive type boiler, two derricks fitted with a 50-ft. boom, clam-shell buckets and a large hopper for sand and stone. Each barge is also fitted with a large centrifugal pump for removing water from the cofferdams. The barges are moored alongside of the work to be done, one derrick being used to hoist sand and stone from supply lighters into the hopper on the barge, from which it is dropped through gates into a measured car, which also carries cement. The car is pulled up an incline built above the receiving end of the mixer, and the material is dumped into the latter, from which the concrete is discharged into a bin. The concrete is picked up from this bin and placed in the forms by a clam-shell bucket handled by the other derrick.

The pile driving is first completed in a pier location and then a wooden cofferdam made up of four portable sections, two sides and two ends, is set in place by a plant constructed for that purpose.

This plant consists of two 24x60-ft. lighters, rigged as a catamaran with the sides spaced 35 ft. apart and held in that position by spacing timbers at each end. The two lighters are each equipped with a 10-ton derrick placed at diagonally opposite corners. Between the barges on each side of the transverse center line of the catamaran are two timbers, 14 ft. apart, on which are operated three trucks on small wheels. The sections of the cofferdam are picked up from the supply lighter and set up in position on these three cars, one car supporting each end, and one the center of the cofferdam, which weighs from eight to twelve tons when the four sides are assembled, braced and caulked. The ends of wales on the four sections of each cofferdam overlap at the corners when the sections are in position and 1¼-in. rods run down through holes in the corners tie the four sections together. The assembled cofferdam is run out on the three trucks on the track timbers between the barges, which have been anchored over the pier location. The weight of the dam is then taken up by falls on an overhead supporting frame on each barge and the cars rolled back on the barges and the cofferdam lowered into position and secured.

Previously to placing the cofferdams, from 17 to 28 anchorage piles are driven in each pier lo-



Cofferdams and Abutment in Place Ready for Lowering.

cation, according to the size of pier. These piles are driven 2 ft. below mean low water with follower. At the same time these anchorage piles are driven the piles forming the bent supports for the arch centers are driven and protrude about 11 ft. above mean low water. These latter piles are used in holding plant for placing cofferdams in position, and in moving the plant from pier to pier, the spacing timbers and track timbers being raised sufficiently high to clear these temporary piles. It is the intention to use the cofferdams over and over again, and when the rods at the corners are removed the sections float free.

When the cofferdam is well secured against the tide and waves, the sand overlying the lime rock and coral is pumped out by a large centrifugal pumping plant. When the bottom is cleared a concrete seal 2 ft. in depth is placed under water. The concrete is discharged by the clam-shell buckets and handled by the derrick booms into the mouth of a tremie supported on a movable platform arranged in such a manner that with very little difficulty it can be moved to any desired location over the cofferdam. The details of this device are shown in one of the illustrations and are as follows: A 4x6-in.x26-ft. timber is placed on top of and bolted to the sheeting of each side of the cofferdam, and on these timbers are spiked 35-lb. rails. On these rails are operated two cars, as shown in one of the illustrations, supporting two 8x10-in.x18-ft. track timbers, which in turn support a car with a built-up framework carrying a conical-shaped sheet-metal hopper to tremie. These cars are run back and forth by an endless rope, and it will be seen from this arrangement that it is possible to operate the entire device in any desired manner so that concreting can be done either transversely or longitudinally in the cofferdam, the spout working between the piles. About 30 cu. yd. of concrete are required for each seal, and under the prevailing conditions it requires about three hours to place this amount of material.

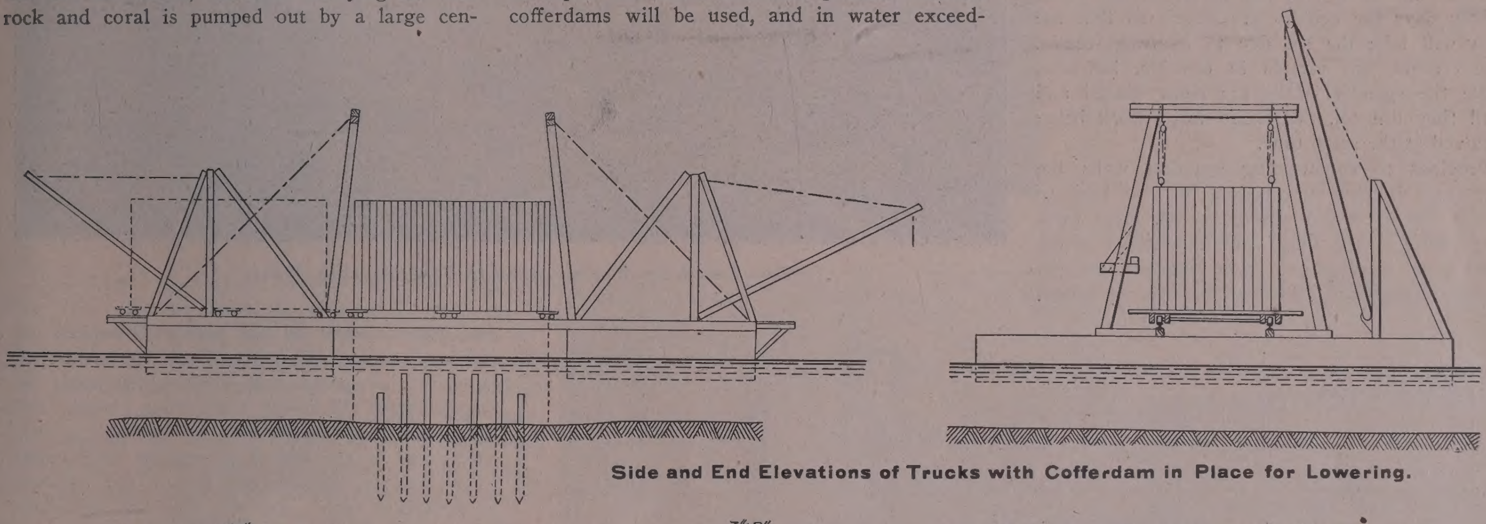
In the first viaduct there are 179 piers and two abutments, one of the latter being 40 ft. and the other 26 ft. high, and the depth of water varying from 7 to 14 ft. In water up to 10 ft. in depth the above described portable wooden cofferdams will be used, and in water exceeding that depth steel sheet piling, made by the United States Steel Piling Co., will be used. This will be driven to about 5 ft. penetration and a seal placed, as is done in all the piers.

After the seal in a cofferdam has been allowed to set for about 7 days, the water is pumped out and the forms for the piers up to mean low water, which is the springing line of the arches, are placed and secured. These forms are made in panels previous to being set in place, and are set up and wired together in the shortest possible time, when they are filled with concrete. Several rods are left out of the pier reinforcement, the purpose of this being to allow two men to stay in the pier form to work the concrete, and to allow the placing of the spout through which the concrete is deposited. When the concrete reaches the top of the pier the spout is removed, the men below come out, the few remaining rods are placed.

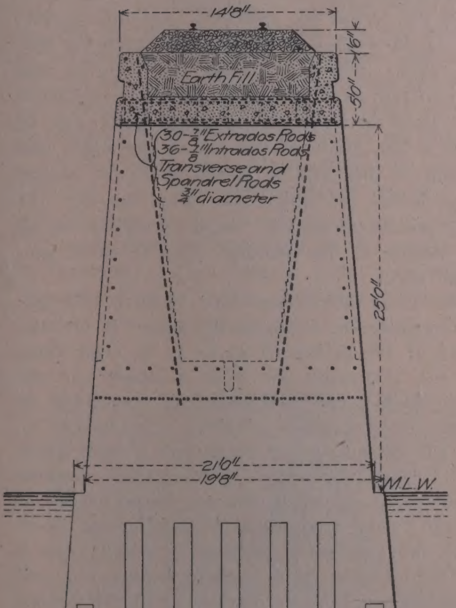
The forms for the upper part of the pier are then placed. The reinforcement rods are also all placed, and the remainder of the concrete laying done at the same time.

During this work the concrete is deposited on a platform on the top of the pier form from which it is shoveled through a chute into the pier. A number of rods protrude from the pier which are to be spliced to other rods in the arch ring and spandrel walls when the latter work is done. These protruding rods are protected from rusting by being given a thin coat of neat cement grout.

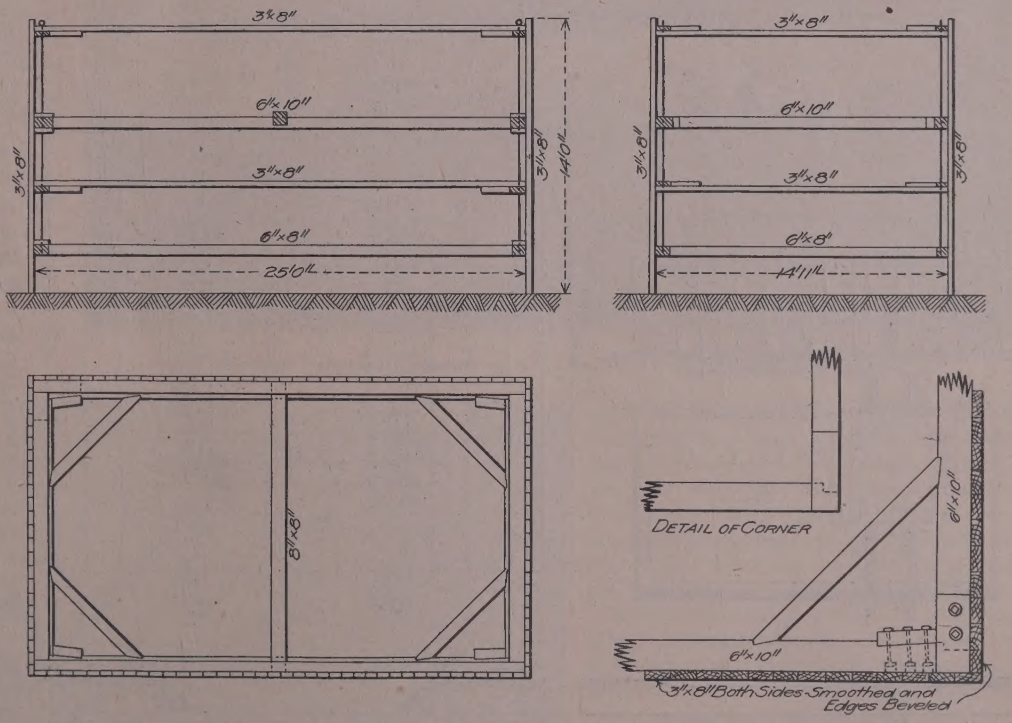
On the completion of the piers and after they have hardened sufficiently, the forms are removed and the arch centers set for placing the arch ring. The arch center consists of five wooden trusses spaced 4 ft. across and lagged up with 3-in. material, and the whole supported on two five-pile bents 28 ft. apart. The centers are held in position by oak wedges. The end chords hang lower than the bottom chords, and are held against the curved face of the pier above the springing line. The outside lines of the concrete are marked on the arch center, and a sufficient height of form work is set to allow pouring the arch ring. As the form work is put into



Side and End Elevations of Trucks with Cofferdam in Place for Lowering.



Section of Viaduct at Center of Arch.



Details of Cofferdam Used in Water Up To 8 Ft. in Depth.

place the steel rods are set and spliced to the rods in the pier, and the whole wired together and fabricated in such a manner that the steel will not be displaced while concrete laying is under way. As the arch ring is concreted, lagging for the back of the arch is carried up on temporary bracing to such a height that the crown can be poured and will not run off on account of the wet consistency of the concrete. In placing the concrete in the arch ring great care is taken to have it thoroughly worked and spaded so that it will come in contact with the entire surface of the steel rods, and that it is worked at the face of the form work so that no voids show when the forms are removed.

When the arch ring has hardened for about twenty days the centers are struck so that the arch will take the set due to its own weight. The centers will remain in position, however, while the spandrel walls are being placed and until they are set, the entire form work being removed at the same time.

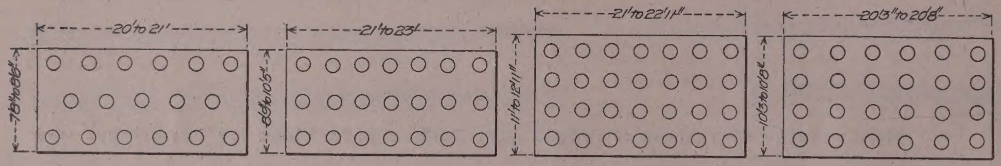
Previous to constructing spandrel walls the temporary bracing and lagging on the back of arch is removed and rigidly braced, form work conforming to the shape and dimensions of the walls is set in place and wired together, and the steel rods used in reinforcing the arch are spliced to the rods protruding from the pier and the arch ring. All rods placed are securely held in position by blocks and wiring before concreting is commenced. The concrete is then raised to the proper height by the clam-shell buckets of the work barge. It is deposited into supported hoppers and spouts, and worked with tools by men between the forms while being placed, care being taken not to disturb the position of the steel, and to see that it is entirely surrounded with concrete, and that the face of the concrete is worked in such a way that no voids will show when the forms are removed. On the completion of the work it is allowed to harden for several weeks, when the forms are removed and the concrete kept wet for a period of ten days. The space between the spandrel walls will be filled to the grade of the top of the walls, and on top of this will be placed 18 in. of broken stone ballast in which the cross ties for the track will be imbedded. Brackets will be set on the outside of the spandrel walls to carry telegraph wires.

Pipe Line from Dredge Used in Transporting Marl.

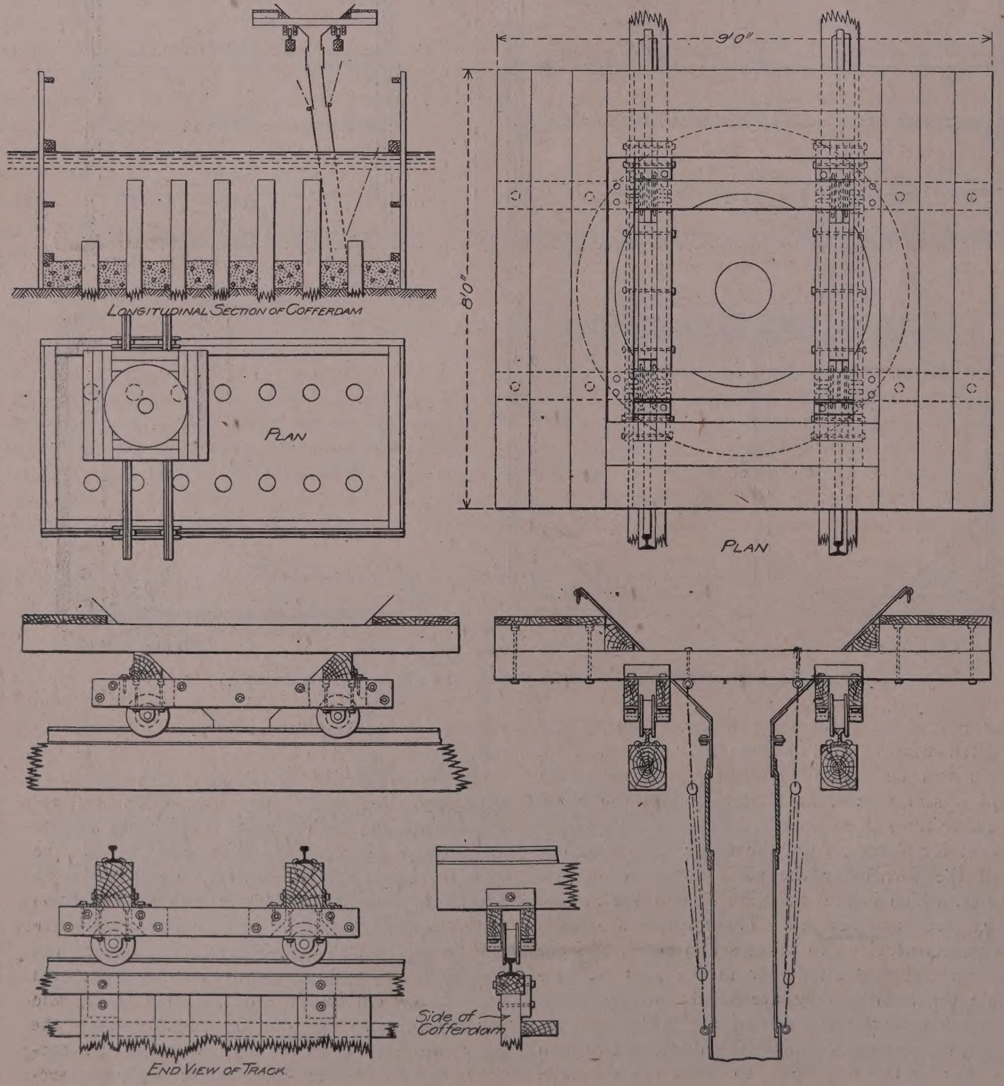
The Long Key-Conch Key viaduct, now under construction, is 10,500 ft. long. It is composed of 180 arches of 45 to 50 ft. clear span, and two abutments, one 26 ft. in height and one 40 ft. high. The first 3,500 ft., containing 62 arches, is on a grade of about 4 in. to 100 ft., and the remaining 118 arches on a level grade 30 ft. above the water. This viaduct requires about 60,000 cu. yd. of concrete, 90,000 barrels of cement, and 1,700 tons of reinforcing bars. There are 181 piers, varying in width from 7 to 11 ft. These piers contain between 17 and 28 piles, according to their size, and about 6,000 piles will be required for this viaduct, for the anhorage of piers and a number of temporary purposes.

The location of the work is in the openings of deepest water between the Florida Keys. One side of the work will be exposed to the ocean, and in extremely rough weather it will be impossible to carry on the work, as in all probability the wave action will exceed in height the walls of the cofferdam, the top of which is about 6 ft. above mean low water, the rise and fall of the tide amounting to about 2 ft. In the event of a storm endangering the cofferdam work, it will probably prove advisable to fill them by allowing the water to run in through a gate arrangement in the wall set at about mean low water. In this way the cofferdam will not be subjected to such great strain and following the abatement of the storm they can be emptied and work resumed.

There has been constructed at Knights Key Channel, in about 20 ft. of water, a 75x600-ft.



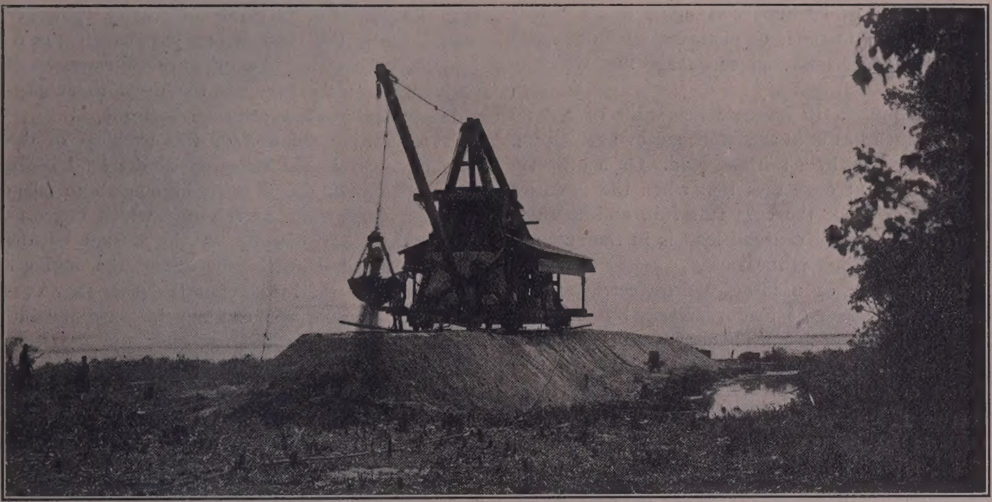
Plan Showing Spacing of Piles in Piers.



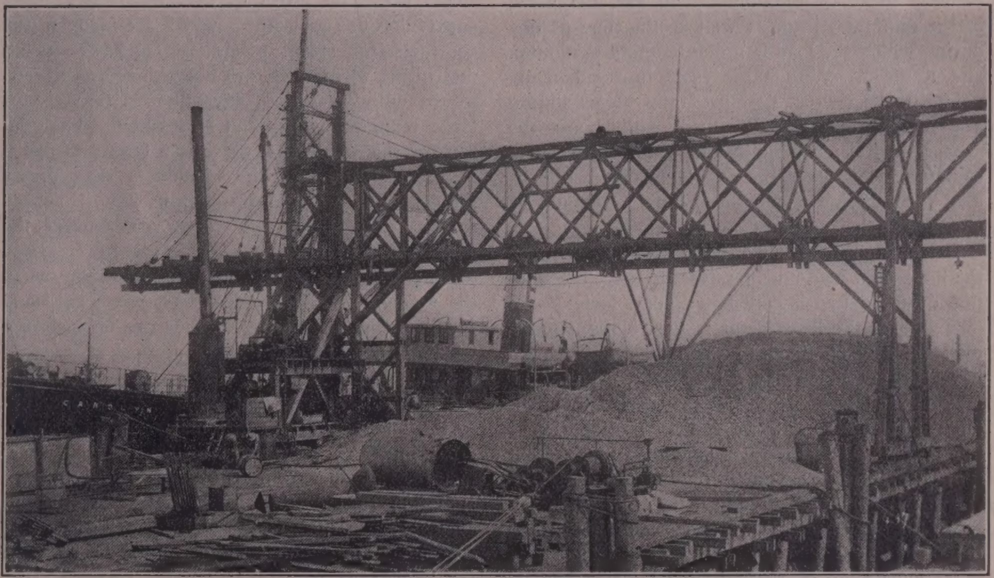
Details of Device for Placing Concrete Seal in Cofferdam.

dock. This dock is used for the storage of crushed stone and screened gravel, and is equipped with a traveling bridge tower, which is rigged in such a manner that stone can be taken directly from the hold of a vessel by a clam-shell bucket and the material deposited on the dock, and in the same manner pick up the stone from the dock and load a supply lighter to be towed to the site of the work. The location of this dock is central to all the concrete work. Crushed stone is brought to it by steamers from New York and screened gravel from Mobile in schooners. The sand used is excavated by dredges at Bear's cut just outside of Miami, and is loaded on barges and towed to the site of the work. The cement arrives in the steamers and is stored in Key West, from which point it is delivered to the work on barges.

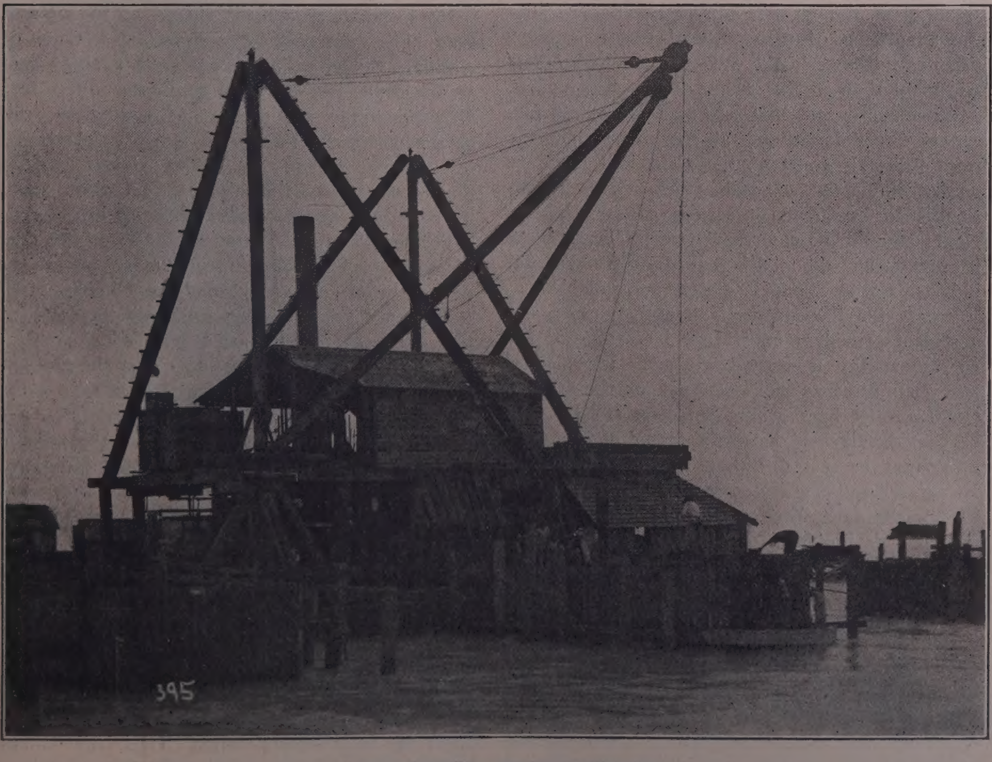
The labor used will be skilled to a great extent. All the men employed by the railroad company on this work are housed and fed in large, clean quarter boats, at the expense of the company. The food is clean and wholesome and of great variety, including fresh meat and ice. The location of the work is healthy at all seasons of the year, and contrary to the general belief it is cool and pleasant in the summer months, in fact, as much so as in the north.



Clam Shell Excavator Building Embankment.



Bridge Tramway Handling Broken Stone at Knights Key Dock.



Lowering Forms in Cofferdam.

The Value and Design of Water Power Plants as Influenced by Load Factor.

A paper read before the Franklin Institute by Dr. Frederic A. C. Perrine.

The load curve of any electric plant varies from hour to hour, from day to day, and in any one year from month to month. These variations are not due to a change in the number or character of the customers for light and power, but to the varying demands of the regular customers from daylight to dark and from season to season.

In any winter day the demand for lighting begins with the needs of the early riser whose habits are fixed by factory whistles and railroad train schedules. At about 6 o'clock the demand becomes the greatest and as the sun begins to show some light the load falls. From 7 to 8 o'clock the load begins to rise again as motors in factories and stores are started when the day's work has begun. From this period until about noon the load remains fairly constant, but between 12 and 1 mid-day the load falls rapidly and the lowest period of the whole 24 hours is reached. At 1 o'clock the load comes on again suddenly to about the amount of the morning load. As the afternoon advances and windows are darkened by the failing light, lamp after lamp is turned on at a slowly increasing rate until about 4 o'clock, when the load begins to mount rapidly, reaching its maximum at about 6 o'clock. At this time there are lights everywhere, in the office, the factory, the kitchen, the dining room, the living room and the bedroom.

Within a few minutes more the load again begins to fall rapidly as the factory is closed and both lights and motors are discontinued. The offices are closed and the janitors have finished their work, the younger children are in bed and the elders have completed dressing and gone to dinner. A dip in the load is then noted; but it increases again to a considerable extent when the theatres open; after they close a rapid fall is perceptible to a minimum which is reached between 1 and 2 o'clock, after which time only the all-night factories and lighting furnish the remaining load.

If readings from the electric measuring instruments have been taken at hourly periods during the day and a curve drawn showing the load on a scale of hours this curve so obtained would be called the "load curve" for that day. The load curve for each day has its distinguishing characteristics. In summer the load would not show a rise in the early morning and in general will be decidedly less in amount during each period of the day, except during the daylight hours, when in any case the power load is the only load served; similarly as we move from month to month the characteristics of the load will change with the changing hours of daylight and work time. From day to day such a curve may be drawn and finally the yearly curve obtained. The term "the yearly load curve" has also been applied to a curve showing the daily volume of the average load throughout the year and also the term has been used to describe the curve showing the daily maximum load for each day of the year.

For the purpose of this discussion, however, we will confine the term "load curve," whether it be a daily or yearly curve, to the true value of the energy supplied per hour throughout this period.

In a study of the problem before us it is necessary to examine this load curve and describe some of its characteristics. First, we notice that the area of any such curve represents the total number of kilowatt-hours supplied to the load. Second, that the average load is obtained by dividing the total kilowatt-hours by the number of hours, and that having drawn a line across the curve at the height of the average load we see by inspection the hourly variation from the mean load. Finally, we obtain directly from the curve the value of peak or maximum load and the value of the minimum load, as well as the time of day during which the load is a maximum, a minimum, and a mean. With these facts in hand many points in the correct design of any power station are readily determined. Such points are the proper subdivision of units, the value of overload capacity in carrying the peak, and the value of load for carrying which the machinery should be operated at its maximum of efficiency.

If from our load curve we obtain the value of the maximum load and the average load, the relation of these two is called the "load factor." In other words the load factor is the relation of the load actually obtained to the load which would have been obtained had a load equivalent to the maximum at any one time been carried throughout the period. As in the case of the load curve this term "load factor" also is applied by different engineers to different quantities. Some apply the term as it has been already defined, which is actually the only meaning which is really justified by the name "load factor." Others claim that it is more expressive of the conditions which control the economy of operation in the plant, if it be defined as the ratio of the average load actually supplied to the maximum capacity of the machinery in operation at any one time. This use of the term is based on the assumption that all machinery in the plant not put into operation at some time for carrying the load must be considered as in the station for the purpose of reserve and that the cost of operation is most largely dependent on the capacity of the machinery at any time in operation.

A definition of the term more directly useful in addressing the problem in this way would be that the load factor is the relation of the average load to the capacity of the machinery in hourly operation, since the maximum station capacity at any time in operation represents a cost of operation in excess of the actual. On the other hand the cost of operation at full load of the machinery which is in hourly operation represents very nearly the true cost of operation.

There are others again who define the "load factor" as the relation of the average load to the total capacity of the station on the ground that the most essenial element of cost is the total installation cost. This latter definition of load factor is always in mind when the value of a hydro-electric station is given flatly in dollars per kilowatt of machinery installed.

The load curve and the load factor are ordinarily controlled by the business management of any plant by choice of character of load. The various customers of any power plant have each a particular load curve which is controllable only within very narrow limits, but the character of loads varies so greatly that it is possible by choice of customers to control the station load factor. This choice of customers is made to an extent automatic by methods of charging which penalize the undesirable load and encourage that which is wanted.

In attempting to increase the value of a load factor much has been accomplished by supplanting a lighting load by a railroad load. On a little reflection one at once sees that when the factories and offices close the cars run full, and furthermore, the greatest railroad load is in the summer when the lighting is the least.

In the case of a large hydro-electric station these two classes of load represent but a single element in the problem. Factories and industries of many kinds must be supplied. Hence it is necessary either to carefully select the load to be carried in accordance with the character of the plant or else to adopt the character of the plant to the probable load curve or load factor obtainable.

To one who has given even an elementary consideration to the problem of coal economy in a steam plant, the effect of load factor is at once apparent. The guarantees which are made in the contracts for steam machinery, and which are met in the plant tests, are not realized as a matter of daily operation, excepting in the case of large pumping plants and steamships. The reason for this is not that there is a trick performed in the tests or that the machinery deteriorates rapidly after original installation, but it is due to the effect of the load factor. Whenever the load factor is unity the full economy realized on the test is also obtained in operation when the management is careful. But when the load factor is less than unity periods are encountered when the load carried is not the most economical and, especially if there are periods when fires are banked, the coal consumption in proportion to the load is increased. This matter is of such great importance that it is difficult with a load factor of 30 per cent. to reduce the coal consumption to less than 5 lb. per kilowatt-hour, even though the steam apparatus at its most economical load will operate on less than 2 lb. per kilowatt-hour.

This matter of load factor often affects the hydro-electric plant more seriously than the steam plant, though it is more generally true that the adaptation of plan to load factor is more often controllable in the design of the hydro-electric plant than in the design of the steam plant.

When the exceptional case of a unity load factor is encountered and at the same time the stream-flow is constant, the plant and load are perfectly adapted to each other. This condition is to be found in certain of the Niagara plants and nowhere else. There the water flow is constant and the load is that of electro-chemical industries whose load is closely controllable.

Where the load factor is less than unity and a stream providing no storage is furnishing the energy, energy is wasted whenever the load is less than the maximum capacity of the stream. On the other hand where sufficient storage may be provided, a load having a factor of less than unity may be served without waste of hydraulic energy. Providing water storage for a variable load is the most direct method in design for attacking this problem.

Certain plants may be designed where the head and storage are simultaneously obtainable, and it is often advisable to sacrifice other elements of design to solve the problem in this manner. For example, the simplicity of plant obtained by the use of a high head has in certain plants already built caused an oversight of the fact that a construction more closely adapted to the condition of loading might have been obtained by changing the location to one of lower head but more than equivalent storage and at a lower cost in proportion to the service to be rendered. Storage sufficient to take care of a load factor of less than 60 per cent. is rarely obtainable in larger plants where the head is less than about 100 ft. for the reason that the quantity of water it is necessary to store becomes too great to be provided in the available storage basins.

A correlative solution of this problem of design is found in the selection of the load itself. The problem of design then becomes a problem in determining rates and is one which concerns the engineer as directly as the design of the power plant itself. No one except the engineer can determine the load factor the plant may economically handle, nor can anyone save the engineer point out to the customer the modifications most readily made in his individual load to enable him to obtain service at the least rate and so obtain for the power plant the desirable load curve. For steam plants this problem has been studied carefully and definite methods are agreed upon for obtaining the highest load factor and the flattest load curve, which is all there is of the problem when using steam, but in the hydro-electric plant the problem and the advisable load curve is different in each case and must be separately solved in each case. This correct solution adds greatly to the value of the plant.

After all has been done that is possible in obtaining the best possible storage and in selecting the most satisfactory customers, it is often the case that there remains a residuum in the problem which may be economically handled only by steam or gas auxiliaries. But a short time ago the presence in any hydro-electric system of steam or gas auxiliaries was considered a confession of weakness in the hydraulic system. Fortunately this false idea is fast losing ground and it is recognized that the best of engineering is shown by their use, and in consequence fine hydro-electric opportunities are being utilized which were previously neglected.

Streams of comparatively constant flow, by the installation of steam or gas auxiliaries, are enabled to supply heavier loads than would be otherwise possible, though perhaps the most important use is found for auxiliaries in cases where the normal stream flow is very materially reduced during short periods of the year, by reason of special conditions in the water-shed.

No hydro-electric plant should at the present time be studied without considering the use of auxiliary power. Oftentimes such a study will result in the rejection of auxiliaries altogether. Oftentimes the employment of auxiliaries will, by the conditions shown, obviously be postponed to a later date than that of the original installation of the hydro-electric plant. But again, when it becomes apparent that auxiliaries are useful, it is immediately necessary to decide on the type of auxiliary installation most closely adapted to the conditions of water supply and loading. In some cases it is advisable to supply the constant load by steam or gas auxiliaries, which are installed in such a manner as to obtain the greatest possible economy of operation, and in such cases the variable load will be supplied from the hydraulic installation. In other cases, the reverse is true, and then the problem presented for choice of the auxiliary is determined by ascertaining the plant which can be installed for the lowest capital charge and fuel charge for the load which the auxiliary plant is to furnish. This in some cases results in the use of uneconomical steam machinery, and in other cases in the use of machinery of the highest grade.

From what has already been said, it is quite obvious that the load curve and load factor are both involved in determining the gross revenue from any hydro-electric plant. It is true that in many cases of plants which have been installed, the revenue is based upon an assumed load factor of unity and charge for current made on the basis of the maximum customer's demand. This method of charging requires a rate lower than might be obtained by a different method of charging, since only those customers who can control their load factor to a value close to unity can afford to enter into such contract, and it is only justifiable where no means can be provided for handling a variable load factor in the plant and where sufficient customers for utilizing all the power furnished by the plant can be obtained. In general, the effect of this crude method of charging reduces the possible earnings.

Where it is impossible to find customers whose load factor is high or adapted to the supply, the value of the plant is consequently and correspondingly reduced, since no matter what may be the method of charging, whether on the basis of a rate per kilowatt-hour or on the basis of the maximum demand, the rate must be figured out in accordance with the type of demand and there is no way of charging which is equivalent to an engineering solution on the problem, which enables the curve of the actual load to be equivalent to the possible supply from the plant itself. An unsuitable load is not necessarily one of a low load factor but is one in which the curve of the load is different from the possible curve of output. A uniform load is unsuitable for a variable stream, whereas a suitable load and in consequence a higher revenue might be obtained from the same stream if a variable load could be obtained corresponding to the variations of the stream flow.

Where the engineering of both plant and load can make the two load curves correspond exactly, the greatest possible output in revenue can be obtained from the hydro-electric plant, whether this be done by steam or water auxiliaries or solely by the engineering of the business department, in order to make the two curves correspond.

The common method of evaluating a water power plant is to state its cost or value in terms of dollars per unit of capacity, as we say that a plant is worth $100, $200 or $300 per kilowatt installed. This method of rating the value of a plant is only suitable where the supply possible from the plant is at a constant rate and the load factor of the customers' load is unity. It is in general very false to reckon the value of a plant upon any other basis than that of its output in kilowatt-hours, which is the true method of reckoning cost and determining the relative value of water power and other sources for obtaining power.

It is true that a considerable proportion of the plants already installed are valued solely upon a basis of capacity and that they are charging their customers upon a maximum demand rate, but it is also true that in a number of these very cases an increase might be made in the revenue if a rate somewhat dependent upon the customers' load curve were adopted. The maximum demand rate encourages no customer save the one whose load factor is nearly unity, and who, in consequence, may supply his needs from other sources of power upon the best competitive terms. When the problem is so considered we see that the maximum demand rate of charging is a low rate for charging, and in consequence the valuation of a plant upon the basis of its capacity alone results in an undervaluation of a large proportion of hydro-electric opportunities. The reason that this is so is that this method of valuation takes no account of the possible load factor or of the cost of power in the particular territory supplied when it may be generated in any other manner.

The true method of valuing a hydro-electric plant is dependent upon its competitive value in the territory, and this requires that it be done upon the basis of the total number of kilowatt-hours which may be generated and sold.

The competitor of a hydro-electric plant is a steam plant and this steam plant runs at an increasing cost per kilowatt-hour with a variable load; in consequence any hydro-electric plant capable of supplying a variable load can obtain from that load a higher revenue per kilowatt-hour supplied than is the equivalent of the minimum stream flow, and often higher than the capacity of the total station. Where the load is adapted to the possible output from the plant a more valuable installation is obtained, even though the minimum of the stream flow may be much less than in a corresponding plant where the minimum flow obtainable is greater but the load is unsuited to a full use of the stream.

The true method of evaluating any plant, whether steam or electric, is on the basis of the kilowatt-hours of output which is salable, and in making this statement we should not by any means neglect the fact that a very considerable item in determining the value of a plant is necessarily based upon the intelligence of the management and of the engineer in establishing rates which will obtain a load adaptable to the possible supply. Following the lead of other stations which are operating profitably often results disastrously to hydro-electric installations when these installations might have been made greatly profitable by a proper adjustment of the loading and charging.

It is much simpler to multiply the rate of greatest possible output by a round number of dollars, but this method gives no idea of what is the true value of the plant. To obtain a value worthy of notice it is necessary to obtain the possible load curve of the customers and from this determine the construction of the plant and its operating cost and then after a similar estimate has been made of the cost by steam or the best other competitive power, an evaluation may be made which is intelligible.

It is not reasonable to develop a hydro-electric station, when a steam or gas station could be built which would supply the same territory at a less cost, but it is also unwise to condemn a hydro-electric development, because the cost per unit of capacity is high, when at the same time it can develop cheaper power than can be done in any other manner.

There is nothing new or revolutionary in these ideas, and they but state the common sense view of the problem, but at the same time the present day usage takes into account only capacity figures with oftentimes added absurdities about "second" power and "short time" power and "night power," none of which can be marketed under the system of charging proposed. A recognition of the true method of valuing such plants which is here described would at the same time result in correct figures and would point out to the management as well as to the engineer what must be done to increase value to the greatest possible figure. This would result in a true evaluation of the hydro-electric development and result in an increase of what is already a large and profitable industry.

A LARGE BLAST was fired last month at the quartzite quarries at Cherbourg, France, from which is obtained a road metal that finds much favor in England. A 6x6-ft. tunnel was driven into the face of the cliff to a depth of 70 ft., and at its end a branch tunnel 20 ft. long was driven to the right and another to the left. These branches ended in 10x6x6-ft. chambers, 40 ft. apart and 70 ft. from the face of the cliff, which were charged with 8½ tons of blasting powder and 2¼ cwt. of dynamite. The blast was fired electrically, and was estimated by the manager of the quarry to have displaced 120,000 tons of stone.

Relative Economy of Turbines and Engines at Varying Percentages of Rating.

A paper read before the American Street and Interurban Railway Engineering Association by Mr. Walter Goodenough of the engineering department of Stone & Webster.

It has become evident to most of us, from time to time, that what is needed in the power station is not so much more economical prime movers, but rather more intensive operation of the particular type of machinery which we now have. This paper has, therefore, been made with the idea that it might bring interesting discussion from many and be of assistance to some of the companies.

The assumption that fixed charges are spread over the whole 24 hours, and that the machine operates during the full 24 hours is, of course, not correct; but in the present instance, where it is desired to bring out rather the effect of the combination of fuel and fixed charge costs, instead of actual operating costs, this assumption is considered to be well taken. On this basis characteristic curves for engine-driven and turbine-driven units are produced.

It is assumed for purpose of this paper that each plant is of one unit running 24 hours per day, and on this basis fuel costs and fixed charges per kilowatt-hour are plotted individually and then combined. No other costs have been taken into consideration, as the addition or subtraction of such constant costs as labor, heat losses, etc., make little or no difference in the characteristics of the curves until these increases or decreases have assumed a very large size. It is further assumed that the labor costs for a single engine-driven unit will be fully as low as for a turbine, and this assumption has also been made for the maintenance of the respective machines. It is taken also that the extra heat turned into the feed water by turbine auxiliaries over those of engine auxiliaries will offset the greater amount of heat used in the work of driving the larger turbine auxiliaries.

In making the curve of fuel cost, the price of coal is assumed at $2 per ton, and the evaporation per pound of coal as 7½ lb. of water. On this basis, 1,000 lb. of water evaporated will cost 13½ cents.

In determining the fixed charges, the following percentages have been taken for engine-driven units: Interest, 5 per cent.; depreciation, 12 per cent.; maintenance, 1 per cent.; taxes, 1 per cent; total, 19 per cent.

For the same charges for turbine-driven units the percentages have been taken: Interest, 5 per cent.; depreciation, 10 per cent.; maintenance, 1 per cent.; taxes, 1 per cent.; total, 17 per cent.

In the above tabulation interest remains standard at 5 per cent.; the maintenance remains the same for both turbine and engine, as any good engine unit will not have a higher maintenance of itself and its auxiliaries than a turbine with its much more numerous auxiliaries. In considering depreciation, amortization has been neglected, and the depreciation deliberately placed high.

In the present state of the art we can expect to see developed in the near future prime movers and fluids generators (including the pieces of apparatus now known as boilers and gas producers) of such an increased efficiency that it will become necessary, for many reasons, to abandon our present units within a few years. We are assured by the makers of turbines that they are still exploring the field, and most of us have visions of high economy gas-driven machinery at no distant date. So unsettled are the conceptions for the future of commercial economy in power generation that it cannot be but wise to place a high depreciation on our present machinery. Competition, local disturbances through municipal ownership, agitation and other commercial reasons will demand more than ever the supersedence of present-day designs for new ones of higher efficiency. The exact form in which "depreciation" is applied does not matter, the basic fact remains that machinery does depreciate, and the fact is not less true that the genus "stockholder" pays the depreciation. He may do it by default of dividends, held in a sinking fund by a careful administration, or by means of assessments, or interest on mortgages or bonds.

In regard to the first cost of the machinery under discussion it has been assumed that with the 500-kw. units the system in use will be 500 volts direct current. It is also assumed that the engine units will have direct-current generators, and the turbine units alternating-current generators, requiring converting apparatus. It is further assumed that the engine will work with saturated steam and that the turbine will use superheated steam. We, therefore, assume the following costs for the engine unit: Engine and generator, $45 per kilowatt; condensing apparatus, $4; foundations, $3; total, $52 per kilowatt. On the same basis we assume that the turbine with saturated steam would cost as follows: Turbine and generator, $36 per kilowatt; condensing apparatus, $6; foundation, $1; motor generator apparatus and switchboard, $22; total, $65 per kilowatt.

In order, however, that full operating value from the standpoint of steam economy may be obtained from the turbine, it is necessary to install with our boilers some superheaters, and for this additional cost we should apply $4.25 per kilowatt, making a grand total for the turbine of $69.25.

In order to show the effect upon the combined kilowatt-hour cost of having to add converting apparatus, Curve "D" in Fig. 1 has been made, based on a total first cost of $69.25, less $22.

For 1,500-kw. units it has been assumed that both the engine-driven and turbine-driven unit will generate alternating current, and on this basis there have been assumed the following costs: Engine and generator, $35 per kilowatt; condensing apparatus, $2.25; foundations, $2.25; total, $39.50 per kilowatt. On the same basis as the above we have: Turbine and generator, $28; condensing apparatus, $5; foundations, 50 c.; superheater and piping, $4; total, $37.50 per kilowatt.

In the case of curves for 1,500-kw. units, it has been assumed, without question, that the engine will run with saturated steam and the turbine with superheated steam.

On the basis of all-size units, operating alternating current, the 500-kw. turbine makes quite a little better showing of rated load efficiency against the engine unit than the 1,500-kw. size. The author would, however, suggest that the 1,500-kw. unit is probably the one size where conditions of total cost per kilowatt, fuel and fixed charges come nearest those of the engine. For all sizes above 1,500 kw. the combined cost of the turbine unit draws rapidly away from the engine unit in the direction of lower cost, and it might be suggested here that if there were any one spot where engine builders desired particularly to apply refinements to their designs in the way of larger cylinder ratios, rejacketing, reheating and superheating, the 1,500-kw. size would undoubtedly prove the most fruitful for them. There is some question, however, as to whether the increased economies in steam consumption they might obtain would overcome the increased fixed charge cost due to greater expenditure to obtain these results.

As stated in the first part of this paper, it is of considerably greater importance in the immediate present to the station manager to consider how he may obtain the greatest economy from the units which he has, rather than where he can buy units having half a pound better steam consumption than what he has.

If we look at Fig. 1, it will be noted that the fuel cost for the 500-kw. engine unit is at its lowest point at 90 per cent. rating, while with the turbine unit this best fuel cost comes near to the 120 per cent. rating, both with and without superheat. Now, if we add to this the fixed charges per kilowatt-hour, we see in our engine unit that the point of maximum economy is moved from 90 per cent. rating to 125 per cent. rating. Also, in our turbine units the point of maximum economy, when converting apparatus is included, is moved up to about 145 per cent. rating from 120 per cent. When the converting apparatus fixed charge is not included, we find the high point of total economy has dropped back to around 140 per cent.

From these characteristic curves, therefore, it becomes quite apparent that we cannot carry our steady loads per unit any too near 100 per cent. rating. It would not, of course, appeal to the average careful station manager to operate his individual units at continuous loads above 100 per cent. Consideration has to be taken of the ability of the generator to stand continuous overload, and a margin has also to be provided for suddenly applied overloads or swings. It would seem, however, that there should be no valid excuse in a well-managed plant for not maintaining the loads as near as possible to 100 per cent. rating of each individual machine. It is well known that engine builders have, for quite a number of years, built their machinery, for point of maximum economy, nearer to 75 per cent. rating than 100 per cent. rating; they assuming that the loads in a station would always be under, rather than up to or over 100 per cent.; and, therefore, they have put their machinery where it would show up the best under loads which the average engineer feels he can run. It is apparent, however, from these curves that the true economy of the plant is by no means the steam economy of the plant, and it is also seen that the engine builder, on the basis of steam economy alone, did not shove his point of best economy far enough back, after all. On the other hand, it appears that the turbine builder has not yet reached consideration of this point, and he is building his turbine for a rating which carries the point of combined economy to considerably over 100 per cent. rating and close up to the point where the total economy begins to fall off sharply, and the capacity of the machine is being rapidly absorbed. In the particular instance of the 500-kw. units, it would seem that the engine overload capacity was not too far in excess of its generator capacity; but in the case of turbine it is apparent that the size of the turbine for the same size generator should be considerably decreased and means taken to insure, after such decrease, that overloads can be readily carried by the machine. Such changes as those would then bring the point of maximum total economy back to the place where it is actually possible to operate the machines under steady loads in the average power station furnishing current for a street railway.

However, the turbine builder has not supplied us with this very desirable machine, and it, therefore, becomes necessary for us to make the best of what we have. It would seem wise to fix as high as possible the loads at which each individual machine in the station should operate, and then maintain these loads as continuously as possible. When variations have to be taken they should naturally be taken by increasing the load on the machines already in service, rather than to put in another unit and underload it, or all of the units in service. There is a question of reliability and safety of service which comes in here, and which the station manager will, of course, have to settle according to the character of his load and the number and size of his units.

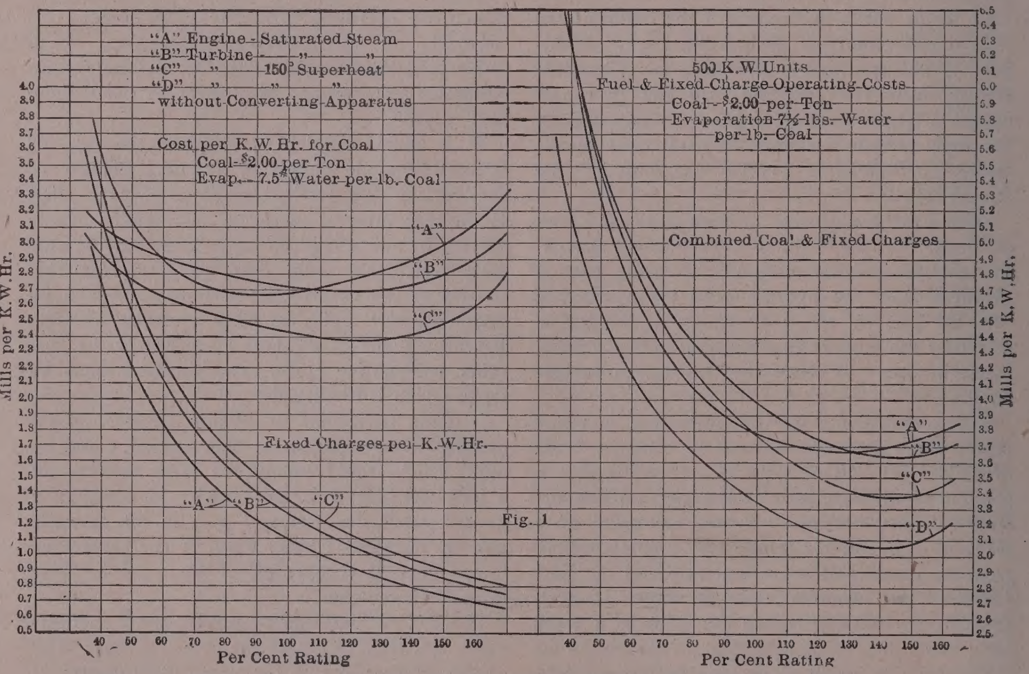


Fig. 1. Fuel and Fixed Charge Operating Costs of 500-Kw. Unit.

The foregoing naturally brings up the question of selection of the size of units in new developments or renewals. The end of all construction should be the minimum combined cost per kilowatt-hour of operation, and, therefore, it behooves us in selecting our new units that we study carefully not only the immediate loads to be applied, but also the expected future loads. It is to be suggested that many managers can, with good success, chart their daily load and fix almost precisely, from day to day, the time when each unit shall enter upon its work and the load which it shall carry. The average station engineer has too limited a view, from reasons of training, to take any initiative of this sort. He will often require considerable persuasion to get him over the fear of running his machinery too hard. It is the author's general experience, however, that with someone to start such a man authoritatively along the lines of better economy, that he becomes, not only anxious to make a better showing, but his pride in such a showing is very marked.

The general statement which has been made that turbines have a flatter load curve than engines is decidedly misleading when considered from the standpoint of total cost per kilowatt-hour. Inspection of the combined curves on both Figs. 1 and 2 show that at 100 per cent. rating the rate of change in cost per kilowatt-hour of operating the turbine is decidedly greater than for the engine. It is seen from this curve that the engine, with its point of steam economy at 85 or 90 per cent. rating, has at 100 per cent. rating a much flatter curve of total economy. If we will inspect Curve "D," Fig. 1, we will see that for an increase in load, from 75 to 100 per cent. rating, the increase in economy on the basis on which this curve is made will be 11 per cent. Of this 11 per cent. gain in total cost the steam economy gain is only 47 per cent., while the fixed charge gain is 23 per cent., or four times as much gain as in steam cost. These percentages, of course, will bear quite some changing under different conditions; but it must be borne in mind that the characteristics of the curves will remain very generally the same.

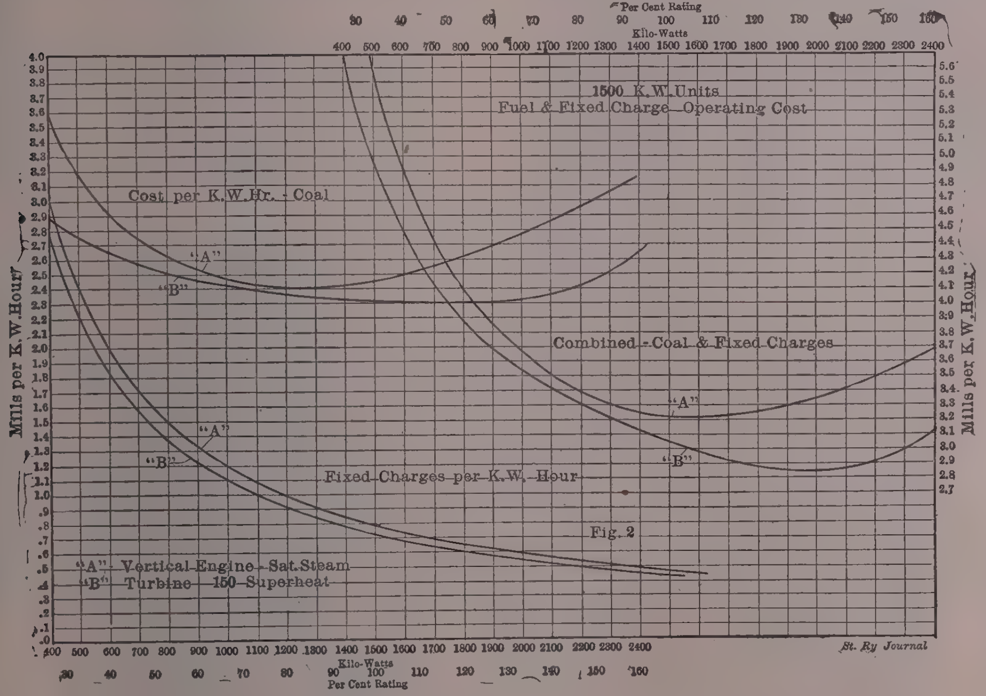


Fig. 2. Fuel and Fixed Charge Operating Cost of 1500-Kw. Unit.

Again, as stated in the first part of the paper, it is not strictly correct to assume that the unit is to run 24 hours a day at a certain load. However, it should be noted that applying the fixed charges to the unit for the actual number of hours run each day will increase these fixed charges per kilowatt-hour, and more than ever increase its effect on the total combined economy, shoving the point of maximum economy still further up into the overloads. The decreasing of the fixed charges per kilowatt-hour means, however, an increasing of the steepness of the fixed charge curve below 100 per cent. rating, thereby accentuating from the other standpoint the marked effect upon total costs which fixed charges have at all ratings below 100 per cent. or thereabouts.

The effect of the increase in the cost of coal, while not affecting the strict character of the curve of cost per kilowatt-hour, does somewhat flatten out the inclined portions of the curve.

Thus it may be truthfully said that the curves "A," "B," "C" and "D" will at all times retain their characteristic forms, and that being the case, whatever has been shown in this paper as to relative costs for different percentages of full load is very closely true. The increase or decrease of either fuel cost or fixed charge cost changing but very slightly the relation of the individual fuel and fixed charge curves to the combined curve.

The point has been raised that, after a plant is once installed the fixed charges do not enter into the economy of operation, and that, therefore, the plant should be run at its lowest steam consumption. If, however, it is legitimate and necessary to figure fixed charges per kilowatt-hour in preliminary estimates, it appears to the author that they should be considered when the plant is in operation, for two reasons.

First, the operating reason, that with the load usually carried by the operating engineer, full value is not being obtained from the investment. A monthly report which shows fixed charges per kilowatt-hour generated should be of immense value to the operating superintendent in determining whether his plant is receiving the particular and discriminating attention which such a large investment warrants.

Second, the investment reason, that a machine which has the lowest combined cost per kilowatt-hour at the individual loading that is carried, is the most desirable to continue in the installation. Manifestly a machine which has a combined kilowatt-hour cost lowest at 100 per cent. rating is better than one having its lowest cost at 140 per cent. rating. The first machine will probably have smaller steam end for the same generator than the second unit. By adding automatic overload devices, costing little money, to the first machine it can be made to operate up to the full overload capacity of the generator in taking care of peaks of short duration.

The author would point out that this is not a consideration of station load factors, but rather a consideration of the economy in operation of individual units, and also economy in their selection as affected by type and design.

In conclusion, the author would additionally point out that the gains indicated herein for turbine and engines are, to a greater or less extent, true for all other station apparatus, and perhaps no more true than in the case of boilers whose load and operation seem equally as far buried under misapprehension as are the generating units.

In Estimating Fuel Consumption for hoisting engines and contractors' machinery, one-third of a ton of coal may be allowed for each 10 h. p. per 10-hour shift. This rule is shown by practice to be a fair estimate for engines up to 80 h.-p.

The Experience of the Boston Elevated Railway with Gas-Producer-Engine Plants.

About a year ago, attention was called in this journal to the decision of the Boston Elevated Railway Co. to construct two small gas-producer-engine stations to supply power to sections of its system rather difficult to reach from the existing steam stations. One plant has now been in operation about four months and the other for a few weeks in a partial way. Both plants were installed with an idea of securing information concerning gas-producer-engine operation by thorough practical test, and are radically different in equipment.

The station at Medford has Wood gas producers and auxiliaries, double-acting two-cycle Koerting engines and Crocker-Wheeler generators. It is in a residential district and the noise of the one engine that has been started seriously annoyed the people in the vicinity, so that the railway company's engineers have been paying attention to reducing this noise and have made no economy tests.

The Sommerville station has a Loomis-Pettibone gas plant, American-Crossley engines and Crocker-Wheeler generators. It began operation on May 4 of this year with one engine, and on May 29 the second engine was started. Both have since been running on week days from 7 a. m. to 11 p. m., and on Sunday afternoons. The engine load factor has been about 74 per cent. Up to Aug. 31, the coal consumption has been 1.45 lb. per kilowatt-hour.

At the Columbus convention of the American Street and Interurban Railway Association at Columbus, a valuable paper on the experience with these two plants was presented by Mr. Paul Windsor, chief engineer of the motive power and rolling stock of the Boston Elevated Ry., from which the following notes have been taken.

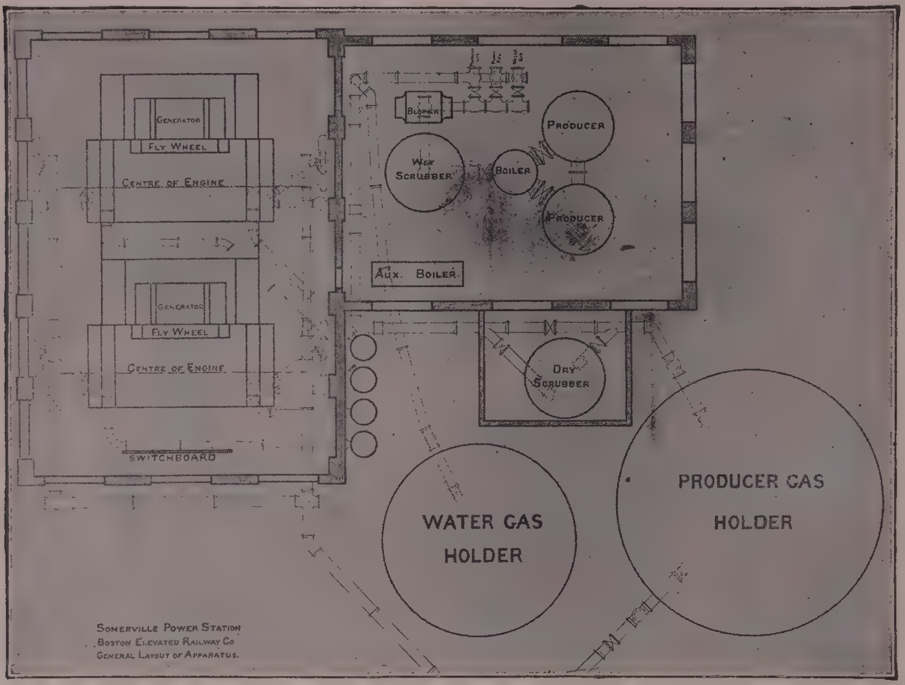
On June 10 a 30 days' test run was begun. During these days the station was run 16 hours per day, from 7 a. m. to 11 p. m., with an engine load factor of a little over 70 per cent. The average Pocahontas coal per kilowatt-hour delivered from the station was 1.31 lb. This included all the fuel used, whether for running the engines, building fires after cleaning, or in the auxiliary boiler.

The plant has proved its reliability, and the shut-downs have been very few. There have been no shut-downs of any kind in the gas house. This portion of the plant has run regularly and without any trouble and has made a uniform grade of good gas. In the engine-room there have been interruptions, but these have almost all been of the kind to which any new power plant is subject. The longest delays, in fact the only real shut-downs, were due to improper water connection with the piston. This matter, however, has been remedied. There has been one case of hot crank-pin, probably due to too quick starting. These engines can be set running so quickly—well inside of 60 seconds, and often close to 30 seconds—that the temptation has been to see how quickly it could be done, resulting, as before stated, in one case of hot crank-pin, the oil not having been given time to reach it after six hours' shut-down.

As a result of his experience with these plants, Mr. Windsor is absolutely convinced of the economy and reliability of a gas engine power station. The fuel consumption will be about one-half as compared with a steam plant, running from less than 1.5 to 1.75 lb., according to the load factor and almost regardless of the size of the plant, as against 3 to 4 lb. in similar steam plants.

The cost of the gas plant, including producers, is undoubtedly considerably higher than the cost of a similar size steam plant, and whether the fuel saved will justify the increased capital depends on the price of coal, but it seems that with coal at $3 and upwards, there will be a material net saving by the use of gas. Another disadvantage of a gas plant is the high efficiency of a small plant, the efficiency being practically the same for engines as small as a couple of hundred horse-power as for those of large size. which, of course, is not true of a steam plant.

The gas-producing portion of such a station is simpler, easier to operate, and holds its efficiency better than a steam plant, according to Mr. Windsor. The losses from banking fires are extremely small, and the plant can be gotten into service much quicker than can a steam plant. Fifteen or twenty minutes are required to get the gas plant into full operation, while of course with a boiler plant it takes from 1 to 1½ hours to get the fires into first-class shape. The ashes have to be periodically removed from the producer. In the Sommerville plant this has to be done while the producers are out of commission and takes about three hours twice a week, although the plant can be run a couple of days longer without cleaning, if necessary. The wet and dry scrubbers have to be cleaned every few weeks, but this work is certainly no more difficult than the work required around a boiler, cleaning soot from the tubes and from the soot-chambers.



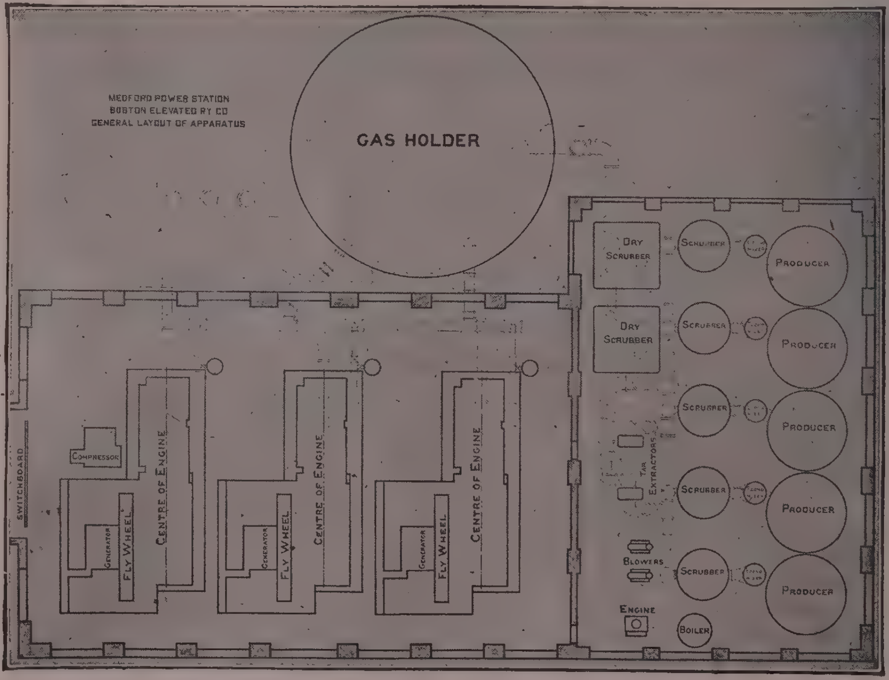
Plan of Somerville Power Station of Boston Elevated Railroad Co.

An ordinary gas man, such a man as would be considered a first-class fireman, can run at least as many horse-power of gas-producers as he can of boilers. He can make a very uniform grade of gas and will get regularly very much nearer the possible efficiency from the gas-producers than from the boilers. Mr. Windsor has found the Ardos Co_2 recorder of great assistance. Without it the gas man would vary his Co_2 from 5 to 7 per cent., while with it he would hold it below 5 per cent.

The handling of the water jackets is extremely simple. The problem comes in the ignition, but with a well-designed gas engine, equipped with a duplicate system of igniters, there would be little, if any, trouble.

A gas engine will hold its efficiency much better than a steam engine. With a steam engine, poorly set or leaky valves will interfere seriously with its efficiency. With a gas engine the effect of improper ignition or valve setting, or even leaky valves, is generally either to cause a knock, therefore at once announcing itself, or to reduce the output of the engine. None of these things materially affect the efficiency without showing also in other ways.

The water required is considerably less for a gas plant than for a condensing steam plant and considerably more than for a non-condensing steam plant. A non-condensing steam plant will use for all purposes from 40 to 50 lb. of water per kilowatt-hour. A condensing steam plant will use from 20 to 30 lb. of steam, and from 600 to 900 lb. in the condenser per kilowatt-hour. A gas plant will use about 200 lb. per kilowatt hour.



Plan of Medford Power Station of Boston Elevated Railroad Co.

The only two serious troubles at the station have been premature explosion and back-firing in the engines and noisy exhaust. The exhausts are now pretty well under control and certainly they can be made entirely unobjectionable, if not noiseless. Premature ignition and back-firing have both given a good deal of trouble, and on both types of engines have at times been so bad as to reduce materially the engine power for the moment. This trouble is now much less than it was, and even if nothing further is done to eliminate it, will not interfere with the regular and commercial operation of the plants.

Soft coal can be used in down-draft producers, such as those in the Sommerville plant, without any tar getting into the gas, the tar being "cracked" on passing through the hot fires, breaking up into gas and some lamp-black, this lamp-black dirtying the scrubber water to such an extent as to make it objectionable if turned into a clear stream. This lamp-black can, however, easily be separated from the water by allowing the water to become quiescent in a comparatively small tank, the lamp-black rising to the surface.

A Reinforced-Concrete Siphon.

In deepening the Manchester, England, ship canal, a 180-ft. siphon has been laid across the bed at Frodsham, between Warrington and Runcorn. In order to increase the depth of the water in the canal by 2 ft. the two courses were open—dredging or keeping in tidal water to the desired extent. It was decided to adopt the latter course, but in order that it might be carried out arrangements had to be made for dealing with the Frodsham sewage and a stream draining the low-lying marshlands in the neighborhood which, under the new conditions, would be subject to floods at high tides. A two-pipe siphon was built to carry this water under the canal into the River Mersey, consisting of 6-ft. iron pipes having an inside diameter of 3 ft. 6 in. The two lengths of pipes were strongly bound together and then covered with a coating of cement 5 in. thick, reinforced by steel wire netting. When completed the siphon was 180 ft. long and weighed 240 tons. It took three days to remove it from the wooden frame in which it had been erected and place it in the waters of the canal. When completed, it was towed 8 miles down the canal, the ends, which were sealed, resting upon pontoons, while a third pontoon supported the center.

Hydraulic Air Compression by the system of entraining free air in flowing water and then conducting the water down a shaft until it is under sufficient head to give the desired pressure, at which point the air is intercepted and piped to the surface, is to be tried at South Thomaston, Me. The principle employed is substantially that used at the well-known stations at Magog, P. Q., and Norwich, Conn., but modified so that the head will be furnished by tidal action.

The New Hydraulic and Cement Testing Laboratories at the University of Pennsylvania.

The new building for the engineering departments of the University of Pennsylvania has a frontage of 300 ft., a depth of 210 ft. at one end and 160 ft. at the other, and is three stories high, with a basement under about one-third of the entire structure, the total floor area being 128,000 sq. ft. The construction is fireproof throughout and the equipment is most complete and modern, the approximate cost of the building and equipment being nearly $1,000,000. The exterior is of dark brick with limestone trimmings, and the general architectural treatment is the English Georgian style. The halls and corridors have Italian marble wainscotings and floors of Tennessee marble. The interior trim is of oak throughout.

The shops, laboratories, drawing and recitation rooms of the electrical, civil and mechanical engineering departments are all brought together in the one building. The laboratories, which are of the greatest interest to the readers of this journal, are the two provided for hydraulic research work and cement testing.

New Engineering Building of the University of Pennsylvania,

Hydraulic Laboratory.—The laboratory for the former work occupies a 39½x63½-ft. space in the basement, a space of the same dimensions directly above it on the first floor and above one end of these rooms on the second floor a 13¾x22-ft. room; a total area of 5,300 sq. ft. The basement and first floor walls are faced with pressed buff brick to a height of 5 ft. and plastered with a sand finish. The floors, including those of several large tanks, are of reinforced concrete. A spiral iron staircase connects the basement and the two floors.

The laboratory is lighted by large windows on one side and by a skylight across one end above the first or main working floor. A large opening in this floor directly beneath the skylight, assists in lighting the basement, although not provided for this purpose. Electricity is used for artificial lighting.

Water for the laboratory is obtained from the city mains through a 4-in. pipe which branches at the point where it enters the building to feed the principal pipe circuits, through which the main supply tank for the laboratory, is filled. This tank is constructed of concrete, plastered with a ½-in. lining of waterproof cement mortar, carefully applied, every effort having been made to secure watertightness. The cross-section of the tank is 22¼ x 19 ft., and its water depth is 7½ ft., giving a capacity of 23,000 gal. On one side a section of the floor is depressed about 3 ft. to form a sump for the suction pipes of the pumps. At the base of the overflow pipe from this tank a 12-in. sluice gate and drain pipe, connecting with the sewer, are provided, for drawing off the contents. This tank contains the general supply for the laboratory, and all water used is pumped from it through the piping system to the apparatus from which it is discharged again into the tank. The only demand on the city supply will be to replace water which has become stale and possibly to furnish a supply for small apparatus under low heads, when for any reason it is not desired to use a pump. In one corner of this tank a water-tight, 8-in. tubular well, 110 ft. deep, passes through the floor. Water is introduced into the well through a pipe extending nearly to the bottom, affording means of regulating the water depth. This well is to be used for efficiency tests and general experimental work with deep-well pumps and air-lifts.

Three main supply pumps are provided. In their selection the following requirements have been kept in view: First, to secure a wide range in head; second a wide range in discharge, and third, to obtain a steady delivery. To meet these requirements the pumping plant has been divided into three units, each consisting of a Worthington 4-in., two-stage turbine pump driven by a 35-h.-p. motor with a range of speed from 520 to 1,040 r.p.m. Each pump is capable of delivering 450 gal. per minute against a maximum head of 165 ft. and considerably larger discharges under low heads. A range in head from about 20 to 175 ft. with corresponding changes in discharge may be obtained with the above range in speed, while the close regulation of head is to be accomplished by wasting from the supply pipe leading to any piece of apparatus. By the division of the pumping plant into units, several pieces or groups of apparatus may be supplied at the same time without mutual interference.

Circuits of 10-in. cast-iron flange pipe are carried on iron wall brackets close to the basement and to the first floor ceilings and are provided at intervals with 6-in. openings for the attachment of apparatus and with gate valves to control the flow or to separate the delivery from the several pumps, when desired. Both circuits connect with a 12-in. stand pipe. This stand pipe is 65 ft. high, with overflows at a number of points. It extends from the basement floor to a short distance above the roof of the building, and connects with the main pipe circuits and with the pressure tank at top and bottom. Any piece of apparatus may be placed under a steady static head, from a few feet to the full height of the stand pipe, by means of circular weirs or overflows, located in the enlarged sections of the pipe, and by the waste pipes therefrom. The flow over the circular weir passes through a 2-in. waste pipe to the apparatus being tested. This 2-in. pipe is controlled by a valve which is closed when a similar overflow at a higher point is in use. A continuous small discharge from the foot of the main waste pipe assures the operator that the required head is being maintained. These overflows are placed at 2½-ft. intervals up to a head of 22½ ft. above the lower orifice opening in the pressure tank and at 5-ft. intervals for the remainder.

A vertical pressure tank designed for a working pressure of 65 lb. per square inch is also provided and is placed at one end of the laboratory. It is of circular cross-section, 5½ ft. diameter, 37 ft. high, including a conical section at the bottom, 11 ft. long. With its connections, at top and bottom, it extends from the basement floor to the second story ceiling. The plates are of ⅜-in. steel, with vertical double-riveted butt joints and horizontal single-riveted lap joints. The former have double straps and ⅞-in. rivets are used throughout. All openings are reinforced and all attachments, except two for orifices, are of cast-steel. A water gage extends from the first floor to the top of the tank. Orifice devices are attached to the pressure tank at the first and second floor levels. The lower is in such a position that the jet from the orifice discharges into a weir tank. Castings are bolted to the inside of the tank, each presenting toward its interior a smooth plane vertical surface about 2 ft. square, through which passes a 7-in. brass bushed hole closed with a brass screw plug. These openings provide for the direct attachment of apparatus. Access to the interior is through a manhole. The tank is surrounded by iron gratings at the floor levels to afford observers on different floors a ready means for communication when engaged on work in connection with the tank.

Advantage has been taken of the difference in elevation of the basement floor and the lower orifice device to make the bottom of the tank conical in shape, with the object of gradually decreasing the velocity of the water as it rises toward the orifice opening. The two devices for holding orifice plates are identical. They are made entirely of bronze and are bolted to the inside of the cylindrical section of the tank. By their use orifice plates can be changed without necessitating the emptying of the tank. Their moving parts present no obstruction whatever to the stream as it approaches the orifice, which occupies the middle of a smooth, plane vertical surface, 3 x 2½ ft., with which it is perfectly flush. This surface forms a chord, the middle point of which is only 4 in. from the inside of the tank, diminishing the cross-section very little. A set of 14 orifice plates with openings of different shapes and sizes has been made for these devices; the circular openings ranging from 0.05 to 0.4 ft.

Two concrete weir tanks are located directly in front of the pressure tank, with their tops flush with the first or main laboratory floor. Each tank is 34 ft. long and has a cross-section of 5 x 5½ ft. They are plastered in the inside with mortar similar to that used for the supply tank, already described. The walls supporting these tanks form a basement store room.

Water is admitted to them at the end next to the pressure tank through 12-in. tees extending the full width of the tank and perforated with a large number of ¾-in. holes, which are so located that the discharge is directed against the bottom and influent end of the tank for the purpose of breaking the strong current of the inflowing stream, an object which is further accomplished by baffle screens sliding in grooves in the side walls near the influent end of the tank. Discharge pipes pass to the floor of the storeroom below and thence to the supply tank below this level. These pipes are closed by heavy cast-iron disk valves faced with rubber. A light wire cable extends from each valve to a groove in an overhead wheel, where it is fastened. The wheels are keyed to shafts crossing the tanks at the first floor level, and each valve is operated by throwing a lever which is keyed at right angles to the shaft.

At the outlet end of each weir tank the walls and bottom are faced with heavy cast-iron angles secured by anchor bolts. To these are fastened three cast-iron plates. The middle plate is bolted to the facing permanently. Its upper edge is beveled the entire length to form a weir either without or with end contractions, the latter requiring the addition of stop plates of which several pairs, of different lengths, are available. An opening in the middle plate provides for large rectangular orifices under low heads, and is closed by a blank plate when the weir is in use. The lowest plate is hinged at the bottom. When in normal position it is drawn by bolts against rubber strips let into the cast-iron facing, thus forming water-tight joints. By fully opening this gate the weir tank becomes a canal, across which dams of varying sections may be placed for the purpose of investigating the flow over their crests. A means of securing these, and other attachments, to the interior of the tank is afforded by vertical angles set flush with the sides of the tank and an angle set in the same vertical plane and flush with the bottom. These are drilled and tapped to receive short stud bolts and are located 8 ft. from the permanent crest. For work with submerged dams or orifices, the discharge will be through the opening in plate or over its crest.

The measurement of heads in connection with the use of the weir tank will be of such frequent occurrence that special provision has been made for putting the hook gages in a favorable position for reading, by placing them securely against the wall of a large gaging pit, the bottom of which is at such a distance below the weir crest that the observer when occupying a comfortable position has the hook of the gage and its scale at the level of the eye. The water is led from each weir tank to the gaging pit through a 3-in. perforated pipe imbedded flush across the bottom of the tank. A glass vessel is connected by a tube with each of these pipes and is supported directly below one of the hook gages on a shelf, the height of which may be varied. The gaging pit is below the first floor and at one side of the weir tanks, and is reached by a ladder. A sectional steel plate cover closes the floor opening when the pit is not in use.

The weir tanks may be used for volumetric measurements by closing the valve controlling the inflow and completely closing the weir end with a plate similar to the stop plates already alluded to, but extending the full width of the tank. When the rate of discharge requires it the two tanks, which have a combined capacity of 13,000 gal., may be used as one by opening an 18-in. square sluice gate provided for the purpose. The floor space claimed by these tanks has been, in effect, reduced, by covering one of them, using interchangeable steel plates supported on light I-beams. The other is left uncovered to receive the discharge from the pressure tank, or from apparatus occupying the adjacent floor.

The delivery pipes of the pumps connect with two 8-in. pipes, into either of which one or more of them may discharge. The higher pipe connects with the main basement pipe circuit and in the opposite direction, with a 12-in. pipe through an expander. The larger pipe is the feed for the weir tanks. The lower 8-in. pipe also connects through an expander with a 12-in. pipe, which is the main feed for the pressure tank, with which it connects at the bottom. Two 10-in. risers lead to the first floor main circuit.

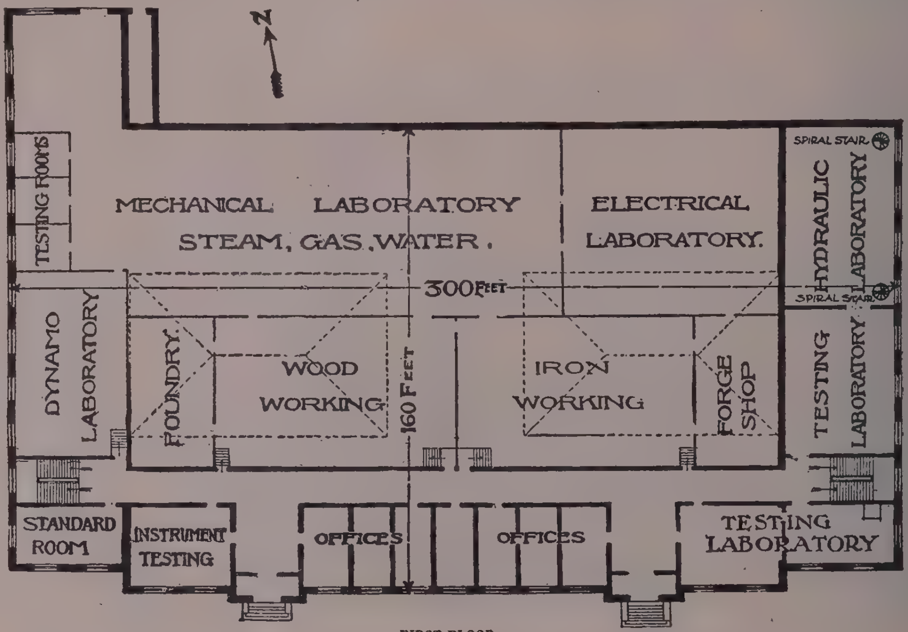
The ordinary gate valve, for water works service, has been used throughout the laboratory. To each is attached an indicator to show the position of the gate, marked "open" and "shut," the space between these two positions being graduated. The arrangement of the piping system has been simplified as far as is consistent with the rather complex service to which it will be put when a variety of experimental work is in simultaneous progress.

A 5½x12½-ft. opening has been left in the basement floor above the supply tank, to receive the discharge from the weirs, and also from two large tanks. These tanks are supported on weighing cars, each with a net capacity of 20,000 lb. Across this opening and extending to the laboratory wall, four I-beams have been built in flush with the floor to serve as tracks for these cars. When it is desired to receive the discharge from the weirs directly into either tank, the car is pushed forward over the floor opening, but usually these cars occupy a position under two closed flumes built along in front of the weir tanks. These flumes receive the discharge from the weir tanks through heavy funnels attached to the end of the latter.

The weighing tanks are constructed of ¼-in. steel and stiffened by horizontal angles. Each has a cross-section of 7 x 5¼ ft., a depth of 7¼ ft. and a working capacity of 1,800 gal. A bell-shaped outlet of cast-iron, 12 in. in diameter, is bolted to the bottom of each tank and is closed by a horizontal disc valve operated by a small quick-action hydraulic lift supported in the tank over the outlet. A four-way valve, fastened to the outside of the tank within convenient reach of the observer at the scale beam, easily and quickly controls the motion of the lift and its attached disc valve. The beams of the weighing cars are counterweighted to balance the weight of the tank, making it unnecessary to allow for a tare.

The steel chutes or closed flumes are suspended below the large opening in the first floor, at a height just sufficient to clear the weighing tanks. The cross-section of each chute is 2 x 1¼ ft.; one is 17 ft. long and the other 10 ft. There are two outlets on the under side of the long chute, one over each weighing tank and one for the short chute. These outlets and valves are quite similar to those used for the weighing tanks and are operated in the same way. The four-way valves which control the discharge from the long chute are connected by a link, so adjusted that as one disc valve rises the other descends. By this means the motion of the water is unchecked and its diversion from the full to the empty weighing tank is accomplished with little effort. The operator occupies a position on the top of the chutes where he has a full view of the first floor, of the water in the tanks and of the observer at the scales.

These chutes are connected with a gutter in the first floor, through which the discharge from apparatus is brought to the weighing tanks. A partition is placed across the gutter between the two outlets to separate the discharge into the two chutes. This gutter has a semi-cylindrical bottom, with a 1 per cent. grade and vertical sides. Its width is 15 in. and depth 15 in. at the higher end. A steel plate cover, in short sections, extends the full length and the inflow of any water which may fall on the adjoining floor is prevented by a low coping close to the edge of the gutter and by floor drains. Two 8-in. circular openings with flush covers afford means for discharging into two calibrated tanks in the basement; each with a capacity of about 800 gal.



FIRST FLOOR.

First Floor Plan of New Engineering Building of University of Pennsylvania.

The basement gutter terminates in the supply tank. It is similar in form to that on the first floor, but somewhat smaller, and has a perforated sectional cover to permit water from the basement floor to enter it. It also receives the drainage from the higher laboratory floors, the discharge from the calibrated tanks, just referred to, and the whole piping system may be drained into it through a valve near the pressure tank, and at the basement floor level.

The minor equipment of the laboratory has, for the present, been limited principally to such additional apparatus as will evidently be needed to illustrate and explain the work of the classroom, the most important of which is that used for measuring heads or pressures. For very small differences in head, differential oil gages are to be employed and, for greater differences, mercury gages of the same class. For heads from 40 to 160 ft. a set of pressure gages is to be used, and to secure sensitiveness each will cover only a limited range.

Flow through pipes is to be investigated by circuits supported against the north and east laboratory walls at a distance from the floor convenient for the observation of gages. These circuits are to be connected with the main piping system through a 6-in. opening. Flanged sections designed to show the loss of head due to sudden or gradual expansion and contraction of cross-section may be placed in these circuits, and the loss of head in valves and meters may also be investigated, although this latter class of work may be conducted as conveniently by other connections with the main supply circuits.

To illustrate the theory of hydraulic motors a 9-in. turbine and a 12-in. reaction wheel have been installed. The former is supported on I-beams above one end of the covered weir tank. It receives its supply from the stand pipe through a short 12-in. connection, and the discharge is weighed or determined by the weir at the other end. Various heads on the wheel may be maintained by the stand pipe overflows already described.

The impulse wheel is mounted in a case with glazed sides through which the course of the jet may be observed. It may be located at any point convenient to the outlets of the first floor main supply circuit and its discharge may be measured in the same way as that of the turbine.

All water discharged above the elevation of the weir tank bottom may be weighed in the two large tanks on the weighing cars. This arrangement excludes discharges in the basement, which is, however, not a serious matter, the space there being largely occupied by the storeroom, pumps, weighing cars and tanks, calibrated tanks and piping. By the use of the weighing tanks, and chutes directly above them, investigations covering considerable periods may be made, thereby minimizing the error in the time observation. It is expected to weigh discharges as great as 4 cu. ft. a second.

The pressure tank, together with the facilities for weighing, provide means for accurately determining coefficients of discharge for orifices, compound tubes and short tubes, and similar coefficients for weirs may also be obtained by weight, the discharge entering the long chute from either weir tank through a large removable funnel which bolts to the side of the chute, the other end resting against the end of the weir tank just below the crest.

The accurate measurement of heads is usually rendered difficult by the unsteadiness of gage columns or pointers, caused by variations in the rate of delivery, and by the trapping of air in the pipes. An attempt has been made to largely lessen the first cause of disturbance by using rotary instead of reciprocating pumps and to avoid the other by laying the main supply circuits with a slight rise toward the open-top stand pipe.

Cement Laboratory.—The cement laboratory has been equipped with funds provided by Mr. Robert W. Lesley, who was a member of the class of 1871 of the University of Pennsylvania. This laboratory occupies a floor space of about 1,700 sq. ft. and is divided into a large and small room by a panelled oak partition. The larger room is devoted to instruction in the standard tests of cement. The smaller room is especially equipped for concrete work and is used also as a research laboratory.

The larger room contains four large slate-top mixing tables each accommodating four students. Each table is supplied with a damp-closet subdivided into four sections, four lockers and drawers for the storage of apparatus needed for routine tests, and two balances placed on a raised shelf along the center of the table. The waste is conveniently discharged through chutes provided for that purpose. Graduated burettes of a capacity of 360 c. c. are mounted between these tables, connected to a water tank, through which water at normal temperature may be accurately and quickly obtained. The lower parts of these burettes are made of a smaller diameter than the upper part, thus permitting of the more accurate gauging of smaller quantities of water.

A large slate-top table supplied with gas outlets is used for mounting smaller apparatus and affords space for special experimental work.

The testing apparatus in this room consists of an Olsen and a Riehle lever machine, a Fairbanks and a Falkenau-Sinclair machine of the shot type, and a 50,000-lb. hand-power hydraulic machine for compression tests. The lever machines are driven by independent electric motors and are designed to admit of the application of the load at a uniform rate varying from 100 to 600 lb. a minute. This room is also equipped with an Olsen mechanical briquette-moulding machine, a Howard & Morse automatic sifting apparatus for cement and sand, and a Bauschinger expansion apparatus.

Nine soapstone immersion tanks variously subdivided and supported on steel frames in three tiers are piped for hot and cold water so that a mixed flow may be supplied at any desired temperature, and are in part provided with adjustable overflow discharge connections for maintaining a continuous flow of water at a variable rate. One of these tanks is supplied with thirty-two small, three-shelved zinc racks for the storage of briquettes.

A large soapstone damp closet is provided in this room divided into two compartments for the accommodation of the larger briquette and beam moulds. A series of cement bins and briquette racks are ranged along one of the walls, each bin having a capacity of one barrel of cement, and the racks, which are sub-divided and numbered for the convenient classification of their contents, provide accommodation for several thousand briquettes. The room contains a large case for the storage of glassware and special apparatus.

The laboratory is equipped with a very complete outfit of smaller apparatus, including balances of various degrees of sensitiveness, specific gravity apparatus and briquette moulds.

A glass enclosed office overlooks this room and the adjoining research laboratory. The latter is equipped with one standard mixing table and its full complement of apparatus. It contains the boiling apparatus for accelerated tests mounted on an iron stand and a drying oven for use in connection with specific gravity and absorption tests.

A large concrete immersion tank capable of accommodating concrete beams 13 ft. long is installed in this room and provided with a special beam crane for the convenient handling of the beams and their transference to special carrying frames mounted on casters designed for their transportation to a 200,000-lb. Olsen universal machine, with permanent table for transverse tests installed in a testing laboratory just across the hall.

A concrete block of suitable height for moulding compression specimens is provided in one corner of the room. Above this block, and back of it, is a case of shelving for the storage of the moulds used in that connection.

Several bins for the storage of stone and sand are provided as well as a wooden mortar box for mixing concrete. This laboratory is further equipped with moulds for making 8x11-in. beams, 13 ft. long, and 8x8-in. beams 9 ft. long.

For the convenient transportation of material to the laboratory a lift with a capacity of 1,200 lb. is installed and furnished with a steel car, mounted on a truck.

The 200,000-lb. universal machine previously referred to, which forms part of the equipment of this laboratory though installed in an adjacent room, is an Olsen three-screw vertical machine fitted with a beam extension 15 ft. long, designed for a working load of 120,000 lb. It is operated by a direct-connected 5-h.-p., two-speed electric motor, and is equipped with an autographic attachment for recording stress-deformation diagrams.

Heat Economy in Factories.

About seven years ago Mr. Henry A. Mavor investigated the cost of power in factories in Great Britain and presented a paper on the subject to the Institution of Engineers and Shipbuilders in Scotland. Although it attracted much attention at the time, the author acknowledged that it was inadequate as a direct treatment of the subject of heat economy, because it failed to take into account many important factors in the determination of such economy in the whole factory, rather than in its separate portions. Accordingly, Mr. Mavor undertook another investigation in which due attention should be paid to the uses of heat for power, warming and industrial purposes. Buyers of equipment, although fully alive to possible economies in individual units, do not always give attention to the economy of the complete organism of which these units form a part. Sometimes isolated improvements are introduced in such a way as actually to neutralize economies arising from the change. This is seen particularly in the case of electric apparatus; it is easy to detect electrical losses, and, consequently, there is a tendency to spend money lavishly in preventing them, although in the same plant the less easily ascertained and sometimes far greater losses of heat by radiation, connection and direct escape of steam are allowed to go on unchecked. A small saving by some new invention or process is apt to be invested with exaggerated importance and not seen in its true relations. There is also a general tendency to adopt the most economical type of engine, as if that engine must be the best under all circumstances.

The importance of securing some method of stating clearly all the elements of heat utilization in a factory led Mr. Mavor to experiment for a time with graphic methods. The extensive use made of the diagrams of heat distribution devised by the committee on the thermal efficiency of the steam engine of the Institution of Civil Engineers furnished an incentive to develop something of the same sort for the heat balance of a whole industrial plant, but the chart became so complex as to be unintelligible. Abandoning, therefore, the graphic method, an attempt has been made to treat the problem after the manner of the accountant, by a series of double-entry accounts dealing with the available data. A thermal balance-sheet produced by this method is intelligible to most business men after a little preliminary explanation, and affords a basis of comparison in terms of heat-units which is universally applicable to the main points requiring consideration. The other elements in the cost of heat production, such as wages, stores, depreciation, etc., can be dealt with in their proper place, and, should this be considered necessary, can be brought into the comparison; but in the first instance attention is focussed on the vital elements of the problem of power.

It is frequently imposible to obtain accurately each individual item for the heat balance-sheet, but it is usually practicable to proceed by means of approximate estimates of the unknown quantities, making thereby a trial balance which gives an approximation to the facts; and by detailed examination and correction of the balance-sheet as each item is ascertained and verified, the unknown or doubtful factors can be narrowed down until the account is sufficiently accurate in detail to represent the facts for the purpose in view. The figures as they emerge tend to check one another, and the elaboration of detail can be proceeded with subsequently from time to time, because it is possible in such an ordered system of accounts to find a place for each isolated observation. The actual observations from the factory can be compared from time to time, and ultimately the balance-sheet will become of real scientific value; while the carrying out of such an investigation tends in itself to direct attention to possible economies in an ordinary way. Economies can often be effected without any considerable capital expenditure, the heat-balance thus becoming a practical tool in the hands of the manufacturer, apart altogether from its theoretical function of dealing on first principles with the problem of heat-production and utilization. This simplification of the problem renders easier the separate study of the important factors which are outside the question of fuel-economy. The heat-balance does not pretend to tell the whole story, but to a large extent it diminishes the complexity of the problem and renders easier the marshalling of facts so that deductions can be made from them.

Having by such means ascertained the heat-economy, and therefore the coal-economy, the other direct costs, *e. g.*, of labor and other charges associated with power-production, can be treated as functions of the coal-weight or of the heat-units. In many factories the heat-balance is useful because it has only an indirect bearing on the cost of production. It is usually found easy to keep a check on the direct productivity of machinery and labor and more difficult to control the indirect costs. This is also true of heat-utilization. It is easy to buy economical steam-engines and boilers, comparatively easy to keep a check on their individual performance, but less easy to ensure and keep a check on the economical transmission of the heat to the boiler and to the engine, and still less easy to control expenditure at heating and drying-apparatus.

Heat Balance Sheet of a Factory, in Millions of British Thermal Units.

Dr.		Million B.t.u.
BALANCING ACCOUNT.		
Work.		
To Engine Account	155.0	
To Heating Account	565.7	
		720.7
Loss.		
To Boilers Account for Chimney Loss	626.6	
To Engine Account for Pressure Loss in Pipes	1.0	
To Engine Account for Radiation and Condensation	673.0	
To Heat Account for Pipe Loss	12.0	
To Heat Account for Lost Steam	116.7	
		1,429.3
		2,150.0
BOILERS ACCOUNT.		
To Balancing Account for 80 tons of coal at 12,000 B.t.u. per lb		2,150.0
To Engine Account for heat returned from hot-well		31.0
To Heating Account for heat returned in hot water from drains		45.6
		2,226.6
ENGINE ACCOUNT.		
To Boilers Account		860.0
HEATING ACCOUNT.		
To Boilers Account		740.0

	Cr. Million B.t.u.
BALANCING ACCOUNT.	
By Boilers Account	2,150.0
BOILERS ACCOUNT.	
By Engine Account	860.0
By Heating Account	740.0
By Balancing Account for Chimney Loss	626.6
	2,226.6
ENGINE ACCOUNT.	
By Balancing Account for 1,000 I.H.-P. for 62 hours at 2,545 B.t.u. per I.H.-P.-hour	155.0
By Balancing Account for loss in steam-pipes, 860,000 lbs. reduced 1°, say	1.0
By Boiler Account by heat returned to hot-well, 860,000 lbs. water at 118° F., namely, 36° above feed-temperature	31.0
By Balancing Account for radiation and condensation loss	673.0
	860.0
HEATING ACCOUNT.	
By Balancing Account for loss of heat from pipes before reaching the stoves	12.0
By Boiler Account, hot-water feed, 400,000 lbs. at 114° above the feed-water temperature of 82°	45.6
By Balancing Account for lost steam	116.7
By Balancing Account for effective radiation assumed at 100 per cent. efficiency	565.7
	740.0

By showing the probable efficiency of each item in a balanced account, attention is directed to all losses—those which can be classified as reducible or avoidable, as well as those which must be treated as essential to the circumstances of the case. The emergence of untried conditions or new uses for power or heat, or of new resources for obtaining them, can by this means be dealt with intelligently; old methods can be reconsidered in the light of new possibilities; and innovations, can be made without injuriously affecting existing arrangements, the total effect being constantly kept in view.

The method proposed by Mr. Mavor is described in some detail in a paper recently read by him before the Institution of Civil Engineers. It can best be illustrated by a sample balance-sheet based upon an actual case investigated. For obvious reasons the figures given do not exactly correspond with the facts; but the deviations from the facts have been made in such a manner as to preserve the qualitative and quantitative relations of the figures, and to represent the facts accurately for the present purpose, without direct reference to individual factories from which data have been obtained.

The balance-sheet is compiled from the following data:

Steam is supplied by four Lancashire boilers, with economizer and superheater in the flue downcast from each boiler, the superheat being about 80° F. The efficiency of the boilers, economizers and superheaters is estimated at about 75 per cent. The requirements of the heating-system are estimated by measurement of the coal-consumption during the night when no power is required. The indicator-cards from the steam engine were measured for steam-consumption, and the total thus obtained was found to agree reasonably well with the total heat debited to the boilers, and with the water measured from the engine-condenser and from the drains of the heating-stoves, the difference being attributed to leakage of steam and water from the heating-apparatus. This difference will be found stated on the debit side of the Balancing Account. The working hours are: engines, 62 hours; heating, 127 hours per week. The balance-sheet bears on the face of it an argument against using a condensing engine in this factory; for although the engine only runs during half the time that heat is required for drying, the engine is rejecting to the condenser heat which could be profitably utilized for the heating-system.

Heat balances of this character are given by the author in his paper for a number of other industrial establishments in order to show how clearly the way in which the heat was used and wasted could be shown. In the discussion of the paper it was stated that Sir William Siemens, Sir Frederick Bramwell and Sir William Anderson had used these balance-sheets, in a less developed form, for dealing with isolated engines and boilers, but apparently Mr. Mavor has been the first to develop them for all the heat operations of a factory.

Charges for Lighting were recently the subject of a decision by the Wisconsin Supreme Court, 108 N. W. Rep. 65, which is of vital importance to public service companies in that State. The court rules that in the absence of legislation restricting the rate of compensation for furnishing gas to the inhabitants of a city, the grant of a franchise to conduct such business carries by implication the obligation on the part of the company to furnish its service at a reasonable price. The State has the right to prescribe the charge to be made, provided the sum fixed is sufficient to afford reasonable compensation. Whether existing or prescribed charges are reasonable is a judicial question the courts may determine, but the power to establish and fix rates for furnishing gas in the future is a legislative prerogative which the courts have no jurisdiction to exercise.

Mechanical Equipment of the Carnegie Library Building Extension, Pittsburg, Pa.—I.

The Carnegie Library Building, at Pittsburg, is being greatly enlarged and extended, for the accommodation of the increased requirements of the library and the educational institute, and to provide for the addition of museums, art galleries and a large hall of architecture and sculpture. The original library buildings and the music hall, which were built in 1893-5, are retained, the extension forming an enlargement which harmonizes in architectural treatment and proportion, and makes it the largest educational institution of the kind in the world. The extended structure occupies a ground plan of about 440 x 660 ft., and has a total floor space of over 15 acres. For the operation of the mechanical equipment of the building there is provided one of the largest power plants that has been installed in a public building in this country, which supplies over 30,000 incandescent lamps, power for over 500 h.-p. in motors, and steam for heating an interior volume of nearly 14,000,000 cu. ft.

The original Carnegie Library Building was a three-story stone structure, 150 x 250 ft. in plan, located in Schenley Park, in the residential center of Pittsburg, and attached to it on the Forbes St. front was built the Carnegie Music Hall, the two combined forming a structure 150 x 375 ft. in plan. In 1900, a large sum of money was donated by Mr. Andrew Carnegie for the purpose of making needed extensions to the library, and subsequently the scheme was extended to include a number of important departures in the addition of museums, art galleries and a hall of architecture and sculpture. As the site at Schenley Park offered ample facilities for expansion, it was decided to enlarge upon the same site extending eastward from the older building. The original structure forms a part of the west side of the new building, which surrounds the former on the Forbes St. and east sides.

The combined building occupies a ground plan of irregular shape with maximum dimensions of 440 x 660 ft., and is, for the greater part, three stories in height, excepting in the book stack section which has eleven floors. It is of stone construction with pleasing treatment architecturally, and has steel and concrete interior construction for fireproofing, little combustible material having been used. The interiors are high, ceiling head room ranging from 14 to 75 ft. All rooms are well lighted, unusual amounts of window area having been installed. Owing to the large amounts of exterior wall exposure, skylighting and window glass, the heating of the building proved not to be an easy problem, and difficulties of considerable magnitude were encountered.

In providing for the mechanical plant of the extension, it was thought advisable to replace the equipment of the original library by a new and more modern installation of sufficient capacity to operate the service of the entire building, as by centralization it was evident that a maximum of economy could be obtained with a minimum of attendance and difficulty of operation. It was further evident that, from the immense size of the building, a power plant of unusual size would be required, a suitable location for which would be difficult to find. Further, owing to the important character and value of much of the contents of the building, it was desirable that the power plant be located at a distance, if possible, which requirement was most advantageously provided for by a ravine or gulley conveniently located nearby, in which a boiler house building could be located, almost entirely concealed from the library building. A site was accordingly secured there for the plant, and piping connections for steam supply to the main building were provided by a tunnel 500 ft. long, cut through solid rock underneath the building directly to the machinery section of the basement. With this arrangement, the disadvantages of steam generating equipment and the handling of fuel with resulting dust and dirt are removed effectually from the building, while the distance is not sufficient to render piping connections difficult.

The mechanical equipment of the new building is of the most complete order, involving electrical generating, heating and ventilating, refrigerating, elevator, vacuum sweeping, and air compressing apparatus, all of which is, on account of the size of the building of large capacity. Power is also required for the steam cooking equipment of the kitchen of a restaurant contained in the building, and for the operation of an extensive book bindery and printing establishment for the library, the latter having two linotype machines and a large cylinder press. One of the most interesting and important portions of the mechanical equipment, is the heating system, which is of unusual magnitude, and involves some unique features.

Front View of the New Carnegie Library Extension, Pittsburg, Pa.

Heating Systems.—The heating of the building has been provided for throughout by direct radiation, the equipment of which has been designed on a generous scale to provide for extreme conditions. While mechanical ventilation has been most extensively provided for by both fresh air supply and exhaust systems, the fresh air supply is tempered only, and with the exception of the music hall, no attempt is made at heating on the indirect system. The heating system has been proportioned upon the thermal unit system, the distribution of radiation depending entirely upon the exposure of the various rooms. Unusual conditions were introduced by the enormous amounts of skylighting over nearly all sections of the building, which, in some cases, constitutes the only exterior exposure. The design of the system provides for maintaining the usual average temperature of 70° Fahr. throughout the building during zero weather; but, in fact, there is sufficient reserve capacity to accomplish these results with outside temperatures considerably below zero.

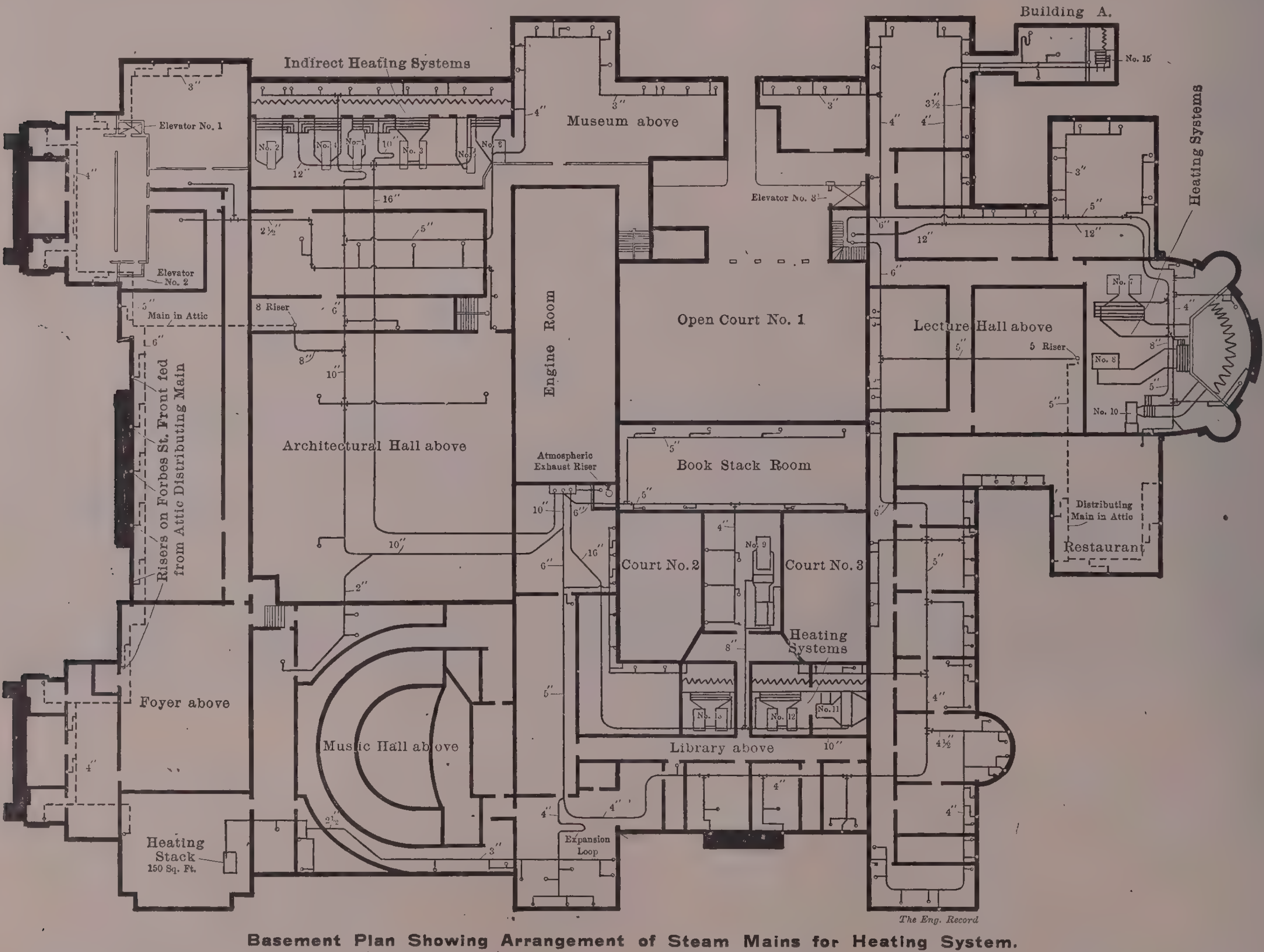
The direct radiation, and the air tempering coils of the ventilating equipments are operated with steam at atmospheric pressure from the exhaust system of the extensive power plant, the Webster vacuum system of steam circulation having been installed. Owing to the immense size of the building embracing a floor area of over 600,000 sq. ft., an enormous equipment of heating surface was required, amounting to over 50,000 sq. ft. of direct radiation, and the steam supply and return piping systems are likewise of great magnitude. The steam supply system consists of nine distinct supply mains which originate at two points in the exhaust steam system in the power plant, namely, at opposite ends of the engine room. Three of these mains, two of which are 16-in. lines and the other a 12-in. line, are devoted solely to the supply of steam to tempering coils of the ventilating systems, which are concentrated at three distinct portions of the basement of the building. The remainder, which embraces one 10-in., one 8-in. and four 6-in. lines, deliver to distributing mains which encircle the outside wall lines of all portions of the building for the supply of heating risers to radiation upon the upper floors. The general arrangement of these mains and the branch connections supplying heating risers, is shown in the accompanying basement plan of the building. These supply and distributing mains are carried upon the ceiling in the basement, graded with the flow of steam and drained to trap relief connections at all pocket points, and all heavily covered with 85 per cent. magnesia pipe insulation covering, with canvas jacketing, which was installed by the Valleau-Costigan Co. Owing to the length of some of the large supply mains provision for expansion were made by U-loops inserted at points mid-way between anchorages, although in most cases, right-angle turns in the pipe lines, made through long radius bends, provide for ample expansion and contraction.

There are in all 116 riser lines carried up for the supply of 36,545 sq. ft. of radiation upon upper floors, which range in size from 1¼ to 2½ in. pipe, and supply amounts of radiation varying from 42 to 972 sq. ft. each. They all have drainage connections at their lower ends and are anchored at the base, expansion being provided for upwards. All that are carried above the first floor are concealed, together with return risers, in chases in the wall construction. Branch connections from the risers to radiation connections are made under the floor in practically all cases, provision for expansion being made by swivel joints. The branch supply connections to the radiators have been fitted in the following sizes: Radiators up to 40 sq. ft. of heating surface, through ¾-in. branches; from 40 to 90 sq. ft., 1-in. connections; from 90 to 160 sq. ft., 1¼-in. connections; from 160 to 250 sq. ft. 1½-in. connections, and all larger sizes by 2-in. supply connections. The return connections are in all cases of ½-in. pipe, except on radiators of more than 250 sq. ft. where ¾-in. returns are used.

The arrangement and distribution of direct radiation was largely the result of conditions of window exposure, all portions of the buildings with exterior windows having in general radiators located underneath them. In the art galleries, the architectural and sculpture halls and other rooms without side window lighting, Bundy circular radiators are distributed in central portions of the floor, by which arrangement both the skylight exposure and the side wall heat losses were counteracted in the most advantageous manner. In rooms with skylighting, special coils were installed to counteract the cooling effect of the exposed glass surface. Special conditions are introduced in these sections by the location of domed lights underneath the main skylighting so that between the domed lights and the skylights there are enclosed air spaces which are effective in reducing largely the heat losses that would otherwise occur through the glass. The skylight coils are located above the domed lights so as to entirely surround the main skylights at the edges, and they were designed with ample capacity for maintaining those enclosed air spaces at sufficient temperatures to prevent serious heat losses from the rooms below through the domed lights. The result of this arrangement has been that in the art galleries, the architectural hall and the hall of sculpture, there is practically no exterior exposure (there being no side window lighting) and very small amounts of floor radiation were installed; the ratio of radiator heating surface to cubical contents in these rooms ranges from 300 to 400 cu. ft. per square foot of radiating surface. In the other rooms of the building where exterior wall and window exposure is encountered, the proportionment follows more closely to general practice, ranging from 80 to 200 cu. ft. of interior volume per square foot of radiating surface, entirely in accordance with the amounts of side window and wall exposure, the distribution of radiating surface having been proportioned on the thermal unit system.

Bundy standard radiators varying from 26 to 48 in. in height and fitted with Jenkins radiator valves on the supply and Webster thermostatic relief valves at the return end, have been installed in the building. The return connections are ½ in. on all radiators up to 250 sq. ft., all larger than this having ¾-in. return valves and connections. The Bundy circular radiators used in the large rooms were resorted to where owing to the absence of side window lighting and the use of the side walls for the exhibition of works of art, the installation of radiators at the side was prohibited. All of the skylight coils are provided with drip pans of 22-oz. copper suspended below them, which have drainage connections to the basement to carry off possible leakage.

All radiation is operated with the Webster vacuum system of steam circulation, which system is particularly well adapted to the conditions of an extensive building plan, with condensation to be returned considerable distances to a central point. The supply mains are paraleled throughout the building by return mains for the vacuum return system which connect with return risers leading to radiation upon the upper floors. There are 114 return risers to the upper floors, into which the Webster thermostatic relief valves on the radiators discharge, of which risers all but nine are of ¾-in. pipe; four of the latter are 1-in. lines and five 1¼-in. lines. The return lines lead to a return header in the engine-room in the sub-basement, from which the air and condensation is pumped by a duplicate equipment of vacuum pumps, returning the water to the boiler-feed system, as will be referred to in a subsequent article descriptive of the power-plant equipment. These pumps deliver first to a 3x6-ft. steel-plate tank with 4-in. vapor connection leading above the roof, by which air and vapor is separated and removed. The condensation flows thence by gravity to the open feed-water heater, from which the boiler-feed pumps at the boiler house take suction. This return equipment, together with the thermostatic return valves, was installed by Warren Webster & Co., Camden, N. J.



Basement Plan Showing Arrangement of Steam Mains for Heating System.

All of the radiation installed is under automatic temperature control, for which the Johnson system of temperature regulation is used. In the principal rooms, large groups of radiators are operated from a few thermostats placed in representative locations to indicate average temperatures, while in the various smaller rooms a single thermostat is usually installed which controls all the radiators provided for their heating; in some cases as many as ten and eleven radiators are controlled from a single thermostat. In an air-supply delivery connection to a smoking room underneath the foyer, there is a reheating coil installed for indirect heating as here radiators were prohibited, and this coil is controlled from a thermostat so located as to indicate average temperatures in that room. There are in all 333 thermostats installed in the building, which together control a total number of 646 heat sources, including both direct radiation and tempering coils. The thermostats are of the standard Johnson pneumatic type, which control the radiation by pneumatic pressure acting through the usual diaphragm steam valves on the supply connections of the radiation. The pneumatic pressure is supplied at about 15 lb. by an air compressor equipment in the engine room, the air supply being distributed to the thermostats throughout the building by a system of wrought-iron piping with armored lead tubing for branches to the thermostats and for connections from thermostats to the diaphragm valves.

A special feature was introduced in the installation of thermostatic control, in the use of push-button control for skylight radiation in some of the larger rooms of the building. In rooms 362 and 364, large classrooms on the third floor at the rear of the building, the skylight coils are thus controlled, a double push-button switch in the former controlling three skylight coils and in the latter a single push-button controlling a single skylight coil. In the control of the tempering coils of the ventilating systems, each of the heating stacks, is controlled in two sections, one by a thermostat located in the cold-air duct, and the other by a thermostat located in the delivery connection. The details and operation of the ventilating equipment will, however, be referred to in subsequent articles.

The heating and ventilating equipment was designed by Baker, Smith & Co., New York, the work having been installed by the Pittsburg branch of the company. The architects of the original building and of the extension were Alden & Harlow, Pittsburg, Pa. Mr. Chas. R. Cunningham is superintendent of the building and the entire mechanical plant will be under his supervision.

(To be continued.)

A High-Head Centrifugal Pump is used for draining a colliery at Wattenscheid, Germany. It has a rated capacity of 176½ cu. ft. per minute to a height of 1,640 ft., when running at 980 r.p.m. It accomplishes this lift in twelve steps, arranged in two sets of six each. In the first a head of 820 ft. is overcome, and in the second a head of 820 ft. more, so that the pump is thus balanced. The pump is electrically driven. Alternating current of 2,000 volts at 50 periods is furnished by a 700-h.-p. Rateau turbo-generator. The turbine has 25 rotors arranged in three stages. The first and second stages are connected, but a journal for the shaft is placed between second and third or low-pressure stage.

The Setting and Care of Fire Hydrants.

With the approach of winter, which the weather prophets say will be a severe one, the superintendents of water-works are necessarily engaged in putting fire hydrants in good condition for resisting freezing. It is accordingly timely to call attention to the recommendations on this subject made by the National Fire Protection Association. They read as follows:

In setting hydrants where the soil is not porous enough to insure ready drainage, place around the base gravel, small fragments of stone or broken bricks to provide a stratum which will absorb water issuing from the hydrant drain in the normal operation. This drainage space should be kept low so as not to contribute to the easy penetration of frost around the hydrant. (Note.—Hydrants in cities are sometimes piped to drain to a sewer. The other means herein recommended are more applicable and simpler.)

Branch pipes to hydrants are more susceptible to freezing than the main line. Hydrants must therefore be of such length as to afford safe cover. (Note.—There is a temptation for men who lay pipe to raise the branch lines when they will not raise the main lines, because they buy hydrants of a specified length for the job, and many times it is comparatively easy and always advisable to put the main pipe low, but rock or some other obstruction makes it equally convenient to put the hydrant high, the result being that the branch pipe at the hydrant, where, naturally, there will not be any circulation, and where, therefore, freezing is more apt to occur, is the least protected of any point in the system.)

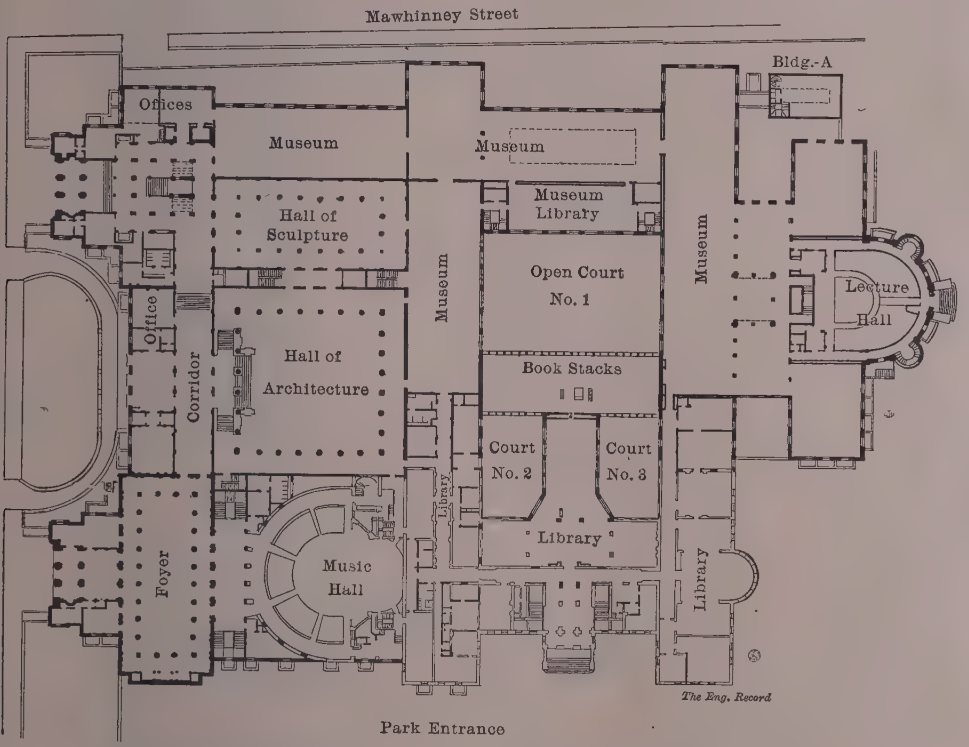


Diagram of Carnegie Library Showing Arrangement of Interior.

In the fall, just before the ground begins to freeze, try every hydrant by running water through it. After it is shut off, examine carefully to see that it is draining properly and that it is in good condition, noting any necessary repairs immediately. (Note.—Be careful that the hydrant valve does not leak, because even if there is good drainage for a reasonable amount of water, continued leakage is apt to fill up the space and cause water to back up into the hydrant. The hissing of a small leak can be heard by placing the ear firmly against the iron casting.)

After two weeks examine the hydrants again without water running through. Small leaks will then have had a chance to fill up the hydrant and show at the hose outlets. Having thus made sure the condition is good, do not use the hydrants again during the winter except in case of absolute necessity, making visual inspection at least once a month meantime.

Hydrants set where ground water stands higher than the hydrant drain should have the drip openings plugged and be pumped out by hand with a pump having a suction pipe suited to be inserted to the bottom of the hydrant barrel, as should any hydrant concerning which the drainage is in doubt.

In using hydrants having independent valves on the hose outlets, the hose gates should be shut last to insure drainage and to prevent leaving the inlet gate open and water in the hydrant. (Note.—A small hole has been drilled in the bottom of the hose valve when this is applied outside the hydrant, through which air may enter and water will issue. The procedure of rule will apply to all types of hydrant in use.)

The practice of putting foreign materials into a hydrant to prevent freezing, notably mixtures containing salt, is not recommended. The presence of salt is apt to induce galvanic action between the dissimilar metals of the hydrant, resulting in injury. Of course, such action takes place right at the valve, the most important part of the device.

To thaw we recommend the application of dry steam. Municipalities usually have a portable boiler which can be obtained. Repeated internal applications of hot water may be used. Only in extreme cases where other means are not available should the heat of a fire be applied to a hydrant, as valves are liable to be injured and it takes time and trouble to repair lead joints.

The Introduction of Safety Appliances on the rolling stock of the Pennsylvania R. R. is now completed. Of the 133,411 freight cars owned on July 1, only 2,496 were not equipped with air brakes, and these have been ordered out of service. A still more important fact is that the company now refuses to accept from other lines cars without air brakes.

Sulphate of Iron and Caustic Lime as Coagulants in Water Purification.

A paper read before the Central Water Works Association by Joseph W. Ellms.

The development during the past five years of the method of using sulphate of iron and caustic lime for coagulating turbid waters, which are utilized as municipal supplies, is both interesting and instructive. It is interesting because their adoption has been hastened by a popular prejudice against the use of alum for such purposes, quite apart from economic reasons which would have eventually caused their employment anyway; and instructive because the method virtually embodies the principles involved in several other well known processes which have been used heretofore with varying degrees of success for effecting the same results. It is hardly worth while examining into the reasons which are the alleged basis for the antipathy of the public toward alum, except to say that sanitarians must pay some attention to the demands of the consumers in this matter even though their aversion to this chemical is quite unfounded. As long as they pay the bills they are not a factor which can be entirely ignored.

In those methods of purification which require the use of chemicals, the cost of the latter is no inconsiderable proportion of the whole, and for this reason sanitary engineers have long been desirous of reducing the fixed charges of operation to a minimum. Since the salts of aluminum and iron appear to be the only ones practically suited for coagulation purposes, the use of the cheaper sulphate of iron in place of the more expensive sulphate of aluminum has long been a great desideratum. But the difficulties in applying the iron salt did not appear to be easily overcome, and as the reasons for these are largely physical and chemical it may be of interest to briefly consider what takes place in a water treated with the above named compounds.

It is usual to speak of natural waters as soft or hard according to the amount of soap which is used up before a lather can be obtained. These terms are merely relative, however, and those salts in the water which use up the soap are the same in both soft and hard waters, merely differing in amount. There are, however, two general classes of salts in a natural water which produce the effect of hardness, but only one of these reacts with compounds like sulphate of aluminum or sulphate of iron when these chemicals are applied as coagulants. This class comprises the carbonates and bicarbonates of calcium and magnesium, and are commonly spoken of as those compounds which produce the temporary hardness of a water. In the case where sulphate of aluminum is applied to a water containing bicarbonates of lime and magnesia in solution, the latter are partially or wholly destroyed, depending upon the amount of alum added. As a result, there are formed sulphates of lime and magnesia which remain in solution and which produce the so-called permanent hardness of the water, and an insoluble compound called aluminum hydroxide which is precipitated. This latter is the coagulating compound and produces an aggregation of the suspended particles into flocculent masses, which settle out to a greater or less degree. In those purification plants where filtration follows the sedimentation of the coagulated matter, a certain proportion of this flocculent material is carried over on to the sand beds of the filters to form the mat which renders possible the rapid filtration of the water.

If instead of sulphate of aluminum, sulphate of iron (copperas) is added to a turbid water containing bicarbonates of lime and magnesia in solution, a somewhat different series of reactions takes place. The sulphuric acid associated with the iron forms soluble sulphates with the lime and magnesia as in the preceding case. The iron reacts with the carbonic acid of the carbonates to form a rather soluble bicarbonate of iron. The iron in both this compound and the applied copperas is in the so called ferrous condition, that is, in a state where it is combined with less oxygen than in the ferric condition or more highly oxidized form. There is a strong tendency for ferrous compounds to become oxidized. The oxygen to produce this change exists in the air dissolved in the water. In consequence of this tendency, the bicarbonate of iron gradually oxidizes and at the same time decomposes into a ferric hydroxide and carbon dioxide. The latter remains in solution and the former precipitates. It is this insoluble, gelatinous ferric hydroxide which is the coagulating compound desired. It has similar physical properties to the aluminum hydroxide obtained from alum, and is generally regarded as equally effective as the alum compound for coagulating purposes.

The chief objection to using sulphate of iron in the manner just described lies in the slow speed of the reactions which have been explained, due largely to the solubility of the product of the first reaction, namely, ferrous bicarbonate. The limited dissociation of the latter compound and its slight hydrolysis, causes the slow production of only very small quantities of ferrous hydroxide. The conversion of this father soluble ferrous hydroxide to the insoluble ferric hydroxide, which is the compound aimed to be produced, is, therefore, only gradually effected. Hence, a water treated with copperas tends to hold the iron in solution so long that its final elimination by sedimentation or by subsequent filtration, if this latter process is used in addition to sedimentation, becomes difficult.

The obvious remedy for rendering the ferrous bicarbonate insoluble and for more rapidly converting it into the insoluble ferric hydroxide, is to take away that portion of the carbonic acid which assists in holding the iron in solution. This can be done by adding caustic lime (or in fact any caustic alkali), which removes a portion of the carbonic acid and causes the reactions to proceed much more rapidly and with far less tendency to reversibility.

The quantity of lime which must be used to effect this result varies with the character of the water being treated. Generally speaking, the greater the temporary hardness of the water the more lime is required. The actual effect, therefore, is not only to remove the carbonic acid which holds the iron in solution, but that also which keeps the calcium and magnesium in solution. A reduction of the temporary hardness results, or in other words the principles involved in the old Porter-Clark process for softening water are utilized. However, this statement only holds good for relatively hard waters, since with low temporary hardness the introduction of caustic lime may actually produce an increase in the total carbonates in solution, although it always reduces the so-called half-bound carbonic acid, which after all is the object sought in this method of coagulation.

If, as in some places, caustic lime is added with the avowed object of introducing a slight excess of this chemical, then not only are the bicarbonates of lime and magnesia reduced, but the magnesium salts are further acted upon with the consequent formation of magnesium hydroxide. This compound is insoluble and has some coagulating properties. The chief effect of the addition of lime in such large amounts, however, is to precipitate more completely the salts of lime and magnesia and thereby produce a softer water. This phase of the process is carried to such an extent in some plants as to quite overshadow the coagulation features. It may be added also that it brings to the front a number of problems which are by no means chargeable to the lime and iron process, and which should be carefully distinguished from those resulting from the use of these chemicals for coagulating purposes only.

The iron and lime method for the coagulation of turbid waters owes its development in a large measure to the study of a patented process known as the Jewell sulphur and iron process, which was formerly used in a number of plants in the Middle West with varying degrees of success. The process, as is well known, utilized the acid solution produced by the absorption in water of the fumes of burning sulphur, to dissolve the scrap iron added to it. The weak iron solution thus formed was applied with caustic lime to the water to be treated. The process successfully demonstrated that iron salts could be used for coagulating purposes with the assistance of lime, and that a fairly good quality of water resulted after filtration. It also appeared that the cost of the chemicals would be less than if sulphate of aluminum was used. It was quite apparent, however, that if sulphate of iron could be obtained at a low enough cost, it could be advantageously substituted, in preparing solutions, for the weak iron solution produced in the patented process.

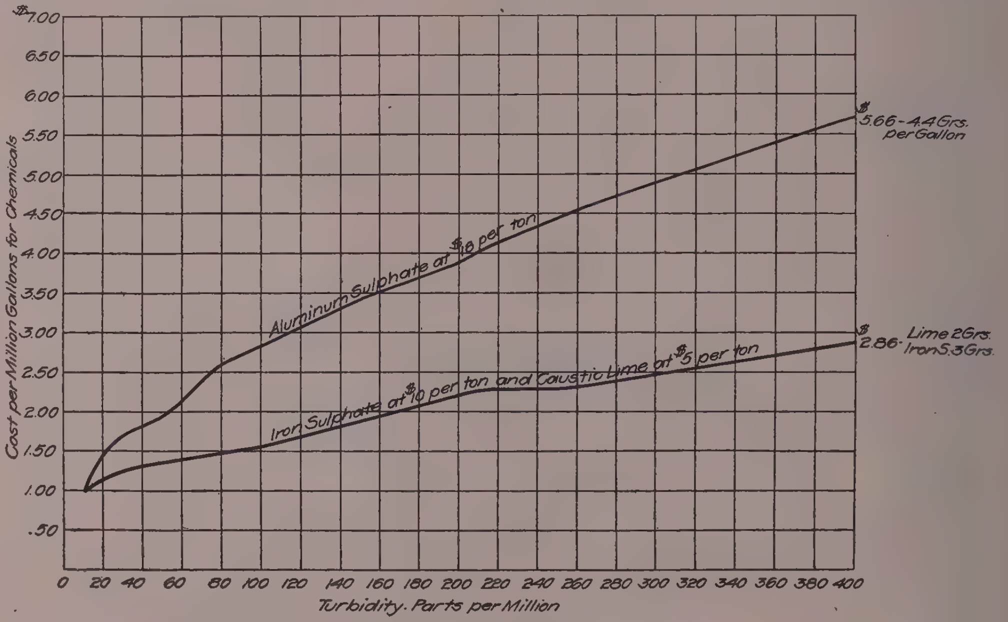


Diagram Showing Cost of Treating Water with Sulphate of Iron and Caustic Lime.

The iron and lime process is indebted to still another very old method for coagulating water known as the Anderson process. This process, which is used in a few places in Europe, makes use of the natural carbonic acid content of the water to be treated, to dissolve a small amount of iron from borings and filings. The water passes through a rotating cylinder containing the iron. By subsequent æration the dissolved iron is oxidized and precipitated as ferric hydroxide, which produces a sufficient coagulation to enable the water to be successfully purified by filtration through sand filters. The process is of limited application, and on account of the power required to rotate the cylinders and the small amount of iron which can be dissolved and made available as a coagulent, could not successfully compete with other processes.

The general applicability of the lime and iron process to water purification is a question which will naturally arise after considering its various features. Its enthusiastic advocates assert that it may be safely and successfully applied to almost any class of water, and its detractors with equal firmness claim there is little good in it. The truth as in most contentions lies somewhere between these extreme statements. A more extended experience with the process will doubtless answer satisfactorily some of the problems which now confront us.

With colored waters, that is, those containing vegetable coloring matter, the applicability of the process is still in some doubt. The well-known tendency for iron salts to form complex soluble compounds with organic matter, which are difficult to decompose and precipitate, appears to be the problem which must be solved. It will probably require more or less experimental work before we can learn what are the limitations of the process in handling this class of waters.

The use of the process in very soft waters offers some difficulties in the proper balancing of the lime and iron applied without introducing an excess of one or the other chemical. In such cases the alkalinity of the water is likely to be so low as to afford a very narrow margin within which the application of the caustic lime may be applied. Still with skillful handling this trouble ought not to be very serious, especially if the treatment of the water is carefully controlled by chemical tests. In the case of very hard waters the coagulation features of the process are, as noted above, likely to become secondary to the softening of the water. As previously explained it does not appear absolutely necessary that this should be the direction the process should take, but there is a strong tendency for it to do so because of the desire to effect as much softening as possible. Herein lies the difficulty, for with increased amounts of lime, increased quantities of calcium and magnesium compounds are formed some of which are slow in precipitating. This is true particularly of the calcium carbonate, which is likely to permeate and precipitate in the sand beds of the filters (where such are used), increasing the size of the sand grains and incrusting the strainer system. These so-called "after deposits" are commonly obtained in all purification plants where softening is an integral part of the process and are by no means peculiar to the iron and lime process. They can be largely avoided by an ample period of sedimentation prior to filtration, but for obvious reasons this latter course is not always possible.

An objection which is frequently raised against the process, is that two chemicals are necessary instead of one, as in the case of sulphate of aluminum. The lime, whether prepared as a milk of lime or as a lime water, is not easily handled or applied. The low solubility of lime in water makes a strong solution impossible, and if lime water is used large volumes of the solution are necessary. If a milk of lime is used the accuracy of the application is impaired, and the emulsion has a number of objectionable features. The use of hydrated lime applied as a dry powder has not yet been satisfactorily worked out. It is unfortunate that the price of caustic soda bars its use in water purification. Its employment in this process would at once solve a number of difficult problems.

The iron sulphate is very soluble in water and offers no more difficulty in the preparation and application of solutions than does sulphate of aluminum. Its tendency to become oxidized may be largely obviated by properly covered tanks, and only sufficient agitation to insure a uniform solution.

In considering the advantages the process offers it should first be clearly kept in mind that the use of iron and lime has passed beyond the experimental stage, and that the process is in successful operation in quite a number of purification plants at the present time. Its most successful application has been to the turbid waters of the Middle West, and it is in this field that it is likely to be most largely adopted.

The chief physical advantage which the use of this process offers is in the rapid sedimentation produced in turbid waters. To those who have not seen the action of these coagulants the quickness with which a water is clarified comes with a good deal of surprise. The coagulum appears to be of a greater specific gravity than that produced with aluminum sulphate. It aggregates in rather small masses, which, however, settle promptly even in a fairly rapid current. The significance of this property of those coagulants is far reaching. It has been a well established fact among engineers for a number of years, that the preliminary settling of turbid waters in order to remove as much of the sediment as possible before applying the sulphate of aluminum, was, in most cases, economical. Without plain sedimentation the increased cost of the chemical required to treat the water and the increased volume of wash water needed, if filters were used, more than offset the interest charges on the capital invested in the construction of preliminary settling basins.

If iron and lime are used as coagulants plain sedimentation may in most cases be eliminated, and relatively small coagulation basins can be made to care for waters carrying an extremely large amount of sediment. For small plants directly from a source of supply liable to sudden fluctuations in turbidity, this ability to handle the water easily without large preliminary settling basins and without excessive amounts of chemicals, is of the greatest importance. Another important feature of this property of these coagulants, when they are used in connection with filtration plants, lies in the diminished amount of sediment thrown upon the filters. The clarification of the water takes place in the coagulation basins, and only enough coagulum need be carried over on the sand bed of the filters in order to form a sufficient mat to properly and effectively purify the water. In other words, by increasing the length of time betwen washings of the filters, the total output of the plant is increased and the proportion of pure water for washing is thereby reduced. The bulk of the work of the purification plant consequently falls upon the coagulation basins, which are less complicated and easier and cheaper to operate than the filters.

The diminished cost of purification for chemicals where iron and lime are used in place of sulphate of aluminum, is in most cases quite marked. The difference in cost in favor of the lime and iron process is greater the larger the amount of sediment which it is necessary to remove. The less the sediment the less this difference becomes. Local conditions are so variable that any general statement as to the amount of this decreased cost in favor of this process would be misleading. But as an illustration Table I has been compiled from data and from estimates as to the amounts of aluminum sulphate and of sulphate of iron and caustic lime required for the successful purification of subsided Ohio River water at Cincinnati. The estimated amounts of aluminum sulphate were taken from data obtained during the experiments conducted by that city in 1898 and 1899. The estimated amounts of iron and lime required have been derived from more or less experience in observing the effect of varying quantities of these chemicals when applied to Ohio River water and from laboratory experiments.

TABLE I.—AMOUNTS OF ALUMINUM SULPHATE AND SULPHATE OF IRON AND CAUSTIC LIME REQUIRED FOR SUCCESSFUL PURIFICATION OF SUBSIDED OHIO RIVER WATER AT CINCINNATI.

Turbidity, parts per 1,000,000.	Sulp. Alumina. Grs. per gal.	Cost per million gal.	Sulph. Iron, grs.	Caustic lime, gal.	Cost per 1,000,000 gal.
10	0.75	$0.97	1.00	0.75	0.99
25	1.25	1.61	1.25	0.90	1.22
50	1.50	1.94	1.40	1.00	1.36
75	1.95	2.51	1.50	1.10	1.47
100	2.20	2.83	1.60	1.20	1.57
125	2.45	3.15	1.75	1.30	1.72
150	2.65	3.41	1.90	1.40	1.86
175	2.85	3.66	2.10	1.50	2.04
200	3.00	3.86	2.25	1.70	2.22
300	3.80	4.89	2.50	1.90	2.47
400	4.40	5.66	3.00	2.00	2.86

NOTE:—Estimates of cost based upon sulphate of alumina at $18 per ton, sulphate of iron at $10 per ton, and caustic lime at $5 per ton.

The tabulated results given above for the cost of treatment have been plotted as curves and illustrate graphically the variation in the cost of chemicals for these two methods. The amounts of iron and lime given for treating the various classes of water are probably higher than will actually be required. The estimated yearly average amount of aluminum sulphate needed for treating the water after plain subsidence is 1.6 grains per gallon, which with this chemical at $18 per ton gives an average cost of $2.06 per million gallons. Assuming the average turbidity of the settled water as 60 parts per million, which is probably too low, the estimated amounts of sulphate of iron and caustic lime required would be 1.50 grains per gallon for the former and 1.0 grain for the latter. With the iron at $10 per ton and the lime at $5 per ton the average cost of treatment per million gallons would be $1.44. This is 62 cents per million gallons less than for the cost of the aluminum sulphate, or a diminished cost of 30 per cent. With waters having a turbidity of only 10 or 15 parts per million there is no practical difference in the cost for chemicals between these two processes; but with high turbidities the increased cost for aluminum sulphate becomes very marked. In the table given above the difference in favor of the iron and lime is 49 per cent., or nearly one-half that of the aluminum sulphate for a turbidity of 400 parts per million. Even greater differences will probably be found in those cases where the water has not received preliminary subsidence.

COMPENSATION FOR EXTRA WORK was recently awarded to a California contractor by the Supreme Court of that State in a decision summed up in 85 Pac. Rep. 929 substantially as follows: Where a contractor agreed to construct a tunnel according to an engineer's specifications, requiring the tunnel to be timbered in a thoroughly workmanlike and practical manner to protect it against outward and inward pressure, the owner furnishing the materials, and during the progress of the work the contractor protested that the timber furnished was defective and the specifications insufficient, he was not responsible for the caving in of the tunnel but was entitled to recover for extra repair work rendered necessary by it.

Use of Steel Ties on the Bessemer & Lake Erie R. R.

The Bessemer & Lake Erie R. R. is owned by the United States Steel Corporation and operated by the Carnegie Steel Co. for all practical purposes, so it is not at all surprising that steel ties are extensively employed on its lines. The experience to date with these ties was recently summarized by the chief engineer of the railroad, Mr. H. T. Porter, in a paper before the Railway Club of Pittsburg, mentioned briefly last week in The Engineering Record. This experience began in November and December, 1900, when about 750 intermediate ties of the Carnegie M-14 trough section were placed south of Osgood in a piece of 100-lb. rail track where the alignment was a compound curve of 6 deg. 30 min. reducing to 3 deg. 30 min., followed by a 9-deg. reverse curve. During the following March and April after the slotted angle bars were received, the joint ties were put in. The track was then ballasted in the usual manner with furnace slag. About one-half of these ties had an angle riveted on the under side at the center, and the balance had an angle riveted on the under side just outside of each rail. The object of the angles was to hold the track in line. They caused some inconvenience in the final lining of the track after it was surfaced. At the time the ties were put in all trains ran over this track, but after May 1, 1902, southbound ore trains and a portion of northbound freights were handled over a new line running to the east, but the rest of the trains continued the use of this track. Trains were operated over the 9-deg. curve about four years without resurfacing. On account of the soft roadbed portions of the compound curve did not run so long. These ties are still in and are giving good service, but are not as satisfactory as those used since.

In September, 1904, there were received about 1,200 Carnegie I-beam steel ties. In November and December, 1904, and January, 1905, 1,000 of these were put in the track about 2 miles north of Euclid, where the track was laid with 100-lb. rails on white oak ties about six years old and ballasted with 6 or 8 in. of slag. The ties were put in by the regular section gang and without any special provision for placing the track in better condition than it was before. Additional ballast was not furnished, and as the space occupied by the steel ties was so much smaller than that occupied by the wooden ties there was not sufficient ballast to half fill the track. Between November, 1904, and June, 1905, the road at this point was single track and carried the entire tonnage of the Bessemer & Lake Erie Railroad. On this section southbound trains are assisted by pushers, and during a portion of the time pushers with 180,000 lb. on the drivers were used. After June, 1905, southbound traffic has been handled over these ties. The supervisor reports that after the steel ties were put in on this curve he had much less trouble in keeping the track in line than he did before, notwithstanding it was hardly half filled with ballast. Considering that from November to June the pushers were backing up around this curve that this track held its line is very significant. Since then 105,000 of these ties have been received, about 70,000 of which have been placed in the track, to give them a thorough test under conditions existing on the road.

Substantially all the freight of this road is handled on that part of the line between Conneaut Harbor and North Bessemer, which is 146 miles in length. The freight tonnage is about 10,000,000 net tons per annum, with an average haul of about 120 miles; the line crosses eight water sheds, and as southbound 30-ft. grades and over are operated with pushers, it has seven pusher districts, covering about 33 per cent. of the road. The curves generally are from 3 to 4 deg., though there are a number running from 6 to 8 deg. On the north 15 miles of this line engines with 225,000 lb. on the drivers and south of this engines with 160,000 and 180,000 lb. on the drivers are used in handling freight trains. As about 8,000,000 tons of freight is ore and coal, loaded so that the gross weight of carload runs from 136,000 to 144,000 lb. per car, producing a load of 34,000 to 36,000 lb. on the axle, and as 60 per cent. of this line is still single track, the service is very severe.

This year two changes have been made in line, one ½ mile long, and the other 3½ miles long. In this work and on all second-track work steel ties are used. On a portion of this work the track was laid with steel ties across a creek bottom and blocked up, and afterward raised to grade by running on it filling in 80,000 to 100,000-lb. capacity cars, loaded to their full capacity, which were then unloaded and used in raising the track. In maintenance work either steel or wooden ties, which ever happens to be on hand, are distributed. Steel ties are used in renewing, whether there be one, two or more ties in a place to be renewed—that is, they are used in the main tracks under all conditions where wooden ties have been used.

Where steel ties are used there is less wear and a more uniform wear of rails. This is accounted for by the better fastening, securing a better connection between rail and tie, preventing the rail from rolling and producing a lateral rigidity in the track structure independent of the ballast. The life of wood white oak ties under heavy traffic ranges from four years on sharp curves to eight or ten years on tangents. There is a wide difference in the durability of timber, even when it is the same kind taken from the same pack of woods. It is beyond the ability of inspector or trackman to select ties that will give the same duration of service. The tie begins to deteriorate from the time it is put in place, the rate of deterioration increasing until it becomes necessary to remove the tie. There is no track work that compensates fully for this deterioration, so a condition equal to an all new tie track cannot be maintained.

The steel tie maintains its section and the bed under the tie does not have to be disturbed on account of tie becoming soft, nor on account of the effective thickness of the tie becoming less, due to rail or tie plate bedding into the tie. The steel tie up to failure retains the same dimensions and efficiency, reducing the work required for surfacing and lining, and it is possible throughout the life of the tie to maintain track of the same excellence as with all new ties. Up to the present time there has been only one broken rail on steel ties and the report attributes this break to a flaw in the rail.

Steel ties have not been used long enough to determine their life under this road's conditions, but an examination of a broken tie after six years' service does not indicate that rusting under ordinary conditions should cause any anxiety. Steel ties have been furnished to the supervisors and section foremen, and they have been asked to freely criticise them. Whereas they do not claim that steel ties perfectly meet all conditions, they want steel ties whenever they can be furnished.

The Hydro-Electric Power Station of the Winnipeg Electric Ry. utilizes a fall of about 40 ft. in the Winnipeg river about 65 miles from the city. A canal 8 miles long leads to the plant, where there are four 1,000-kw. and five 2,000-kw. units, each having a Morgan-Smith turbine, Lombard governor and three-phase General Electric generator. Current is generated at 2,300 volts and stepped up to 60,000 volts for transmission over duplicate lines.

The Trust Company of America Building.

Work is well advanced on the foundations for another tall office building in the financial district of New York City where a decided impetus has been noticeable within the last few months in the replacement of office buildings, some of them of good height and in good condition, by much taller structures which considerably overtop the average steel-cage buildings heretofore built in this locality. The new building at 41 Wall St., for the Trust Company of America, is adjacent to the Mills Building and to the United States Trust Co. Building, and has a front of 61 ft. and a depth of 130 ft., with two stories below street level and twenty-five stories above, carried up to a total height of 330 ft. above the curb. The style is Italian renaissance with a Colonial effect and the front is finished with white marble up to the eighth floor and above the twenty-second floor, the intervening space being of special red brick. The pneumatic caisson foundations are carried through quicksand, gravel and hardpan to rock at a depth of about 80 ft. below the surface. These are arranged in three longitudinal lines supporting the usual concrete piers with grillages and distributing and cantilever girders above to receive the column loads and transmit them concentrically to the piers. The superstructure is of the standard steel-cage construction provided with knee braces to resist the heavy wind stresses in the comparatively narrow transverse section of the building. Over the main banking room, the twenty-three upper stories are carried by exceptionally heavy transverse triple-web plate girders 9 ft. deep and 42 ft. long, and the other framing in the building is of ordinary character except that some of the columns are unusually heavy to provide for maximum stresses of 2,684,000 lb. The floors and roof are of hollow-tile construction, which is also used for fireproofing the columns and exposed girders. All the floors are finished with cement or terrazzo and all of the trim is of fireproof wood. The side windows are glazed with wire glass, partitions are made with hollow tile and cast-iron is eliminated except for ornamental purposes.

The mechanical equipment includes a battery of three 200-h.-p. Franklin water-tube boilers, six electric elevators and electric lighting plant operated by General Electric dynamos and extensive systems of fire protection, water supply and sanitary apparatus and a vacuum cleaning plant. The first three stories of the building are provided with a fan system for indirect heat and ventilation, and the remainder with direct steam radiators. The building provides on every floor direct communication with its Wall St. entrance for the adjacent Wall St. Exchange Building. It has a total rentable area of 5,000 sq. ft. in each of the regular office floors, and has an estimated cost of $1,000,000 exclusive of the value of the site.

Mr. Francis H. Kimball is the architect; Purdy & Henderson are the consulting engineers for the structural steel work; Griggs & Holbrook the consulting engineers for steam, electricity, heating and ventilation. Mr. W. C. Tucker, consulting sanitary engineer. The George A. Fuller Co. is the general contractor. The Foundation Co. is the contractor for the sub-structure, and the Otis Elevator Co. is the contractor for the elevators.

The site was previously occupied by buildings eight or nine stories high with very heavy self-supporting stone walls. These buildings were of excellent and massive construction and in such good condition that their removal occupied several weeks longer than the time allowed and correspondingly delayed the new construction, although the contractor worked vigorously on them day and night. In order to maintain the service in these buildings as long as possible, their tenants were not disturbed until the adjacent building had been underpinned and everything was in readiness for the demolition of the old structures.

The underpinning was therefore accomplished while all the buildings were occupied and was done without interfering with their tenants or with the tenants in the buildings underpinned. It was done without entering the adjacent buildings and without interfering with the power plant and other service in the buildings aftrwards demolished. This was effected by the use of the Breuchaud process, which has been frequently described in these columns, and consists essentially of sinking vertical sectional piers to rock or hardpan in recesses cut in the face of the wall, using the weight of the latter for reaction and conducting all operations from one side of the wall without at any time diminishing the foundation support.

In order to avoid interference with the plant in the cellars of the buildings afterwards removed, the heavy stone sidewalk in front of them was replaced at night by a timber platform in the same horizontal plane. Through a trap door in this platform the machinery and materials necessary for the underpinning were introduced at night without interfering with street traffic. The machinery was installed in the sidewalk vault where it did not interfere with the tenants or with the ordinary service of the buildings. Recesses 3½ ft. wide and about 8 ft. high and 10 ft. apart on centers were cut through the footings and lower part of the brick walls to receive the underpinning cylinders 10 ft. apart on centers. These recesses were cut entirely through the 2-ft. walls of the buildings to be removed and were continued about 44 in. beyond in the adjacent walls which were to be underpinned, but did not penetrate the inside faces of the latter.

Each recess was made by boring about four hundred 2-in. holes nearly 6 ft. long through cement laid brick masonry. This proved so hard and sound that not more than about five holes could be drilled in twelve hours by one machine, and the materials were so strong that when the spaces between the drill holes were broken out with wedges and hammers, the fractures occurred through the bricks rather than in the cement joints. The cutting of the recesses, slow at best, was still further delayed by restrictions permitting the work to be done only between the hours of 5 p. m. and 9 a. m., so that the noise and vibration should not disturb the tenants in the offices. The work was commenced with a 2-h.-p. and a 4-h.-p. Crippen Manufacturing Co.'s electric drills. These were used to cut through the first wall, after which they were replaced by two Ingersoll-Sergeant steam drills with 1¼-in. bits, which were found to give better satisfaction in the deep holes and hard material and were used to cut the remaining 44 in.

The recesses were cut alternately and in each of them was placed a special 4-ft. section of 3-ft. rolled steel pipe made with a reinforced cutting edge. This was forced down vertically into the soil by a pair of Watson-Stilman, 60-ton hand power hydraulic jacks reacting against a horizontal wooden block in contact with the upper edge of the recess. As the cylinder was sunk the interior was excavated and when sufficient room was secured, a second 4-ft. section of cylinder was bolted to the top of the first with a 2½-in. horizontal steel diaphragm plate pierced by a 24-in. hole in the center, inserted between their flanges. The jacks were replaced, sinking was resumed and additional 4-ft. sections, without separating diaphragms, were assembled and the operations were repeated. When the cutting edge reached the ground-water level an air-tight door opening downwards was fitted to the diaphragm between the first and second sections, air pressure was admitted below it and that part of the cylinder was used as the working chamber. The sinking was then continued by the pneumatic caisson process until the cutting edge reached rock at a maximum depth of about 72 ft. below the Wall St. curb.

The rock was overlaid with a 13-ft. stratum of hardpan through which the cylinders were sunk much more slowly than was the case in the loose earth and quicksand above. Numerous boulders were encountered, some of them of large dimensions and frequently located under the cutting edge of the cylinder so that it was necessary to drill and blast them. The sand and earth was excavated by small scoops and hoisted in canvas bags. The hardpan did not require blasting, but was cut out with some difficulty by hand. Only one man could work in the cylinder at once and he excavated the hardpan with a tool made by cutting off one side of a pickax close to the helve and by shortening the handle. The cylinders were sunk entirely by dry excavation without the use of a water jet and required a maximum air pressure of 24 lb. and an average pressure of 18 lb. The surface of the rock was dressed to remove the decayed portions and give uniform bearings on the sound stone and the working chamber was filled with 1:2:4 Alpha Portland cement concrete set under pressure, after which the upper part of the cylinder was filled with concrete under atmospheric pressure. Four men working continuously in eight hour shifts sunk one cylinder and filled it with concrete at an average time of 7 days.

The cylinders, manufactured by the East Jersey Pipe Co., Paterson, N. J., were made of ⅜-in steel, with two longitudinal lock bar joints. Interior horizontal circular angles were riveted to them at both ends to provide flanges for connecting successive sections. Some difficulty was experienced through slight variations in the diameters of the cylinders and through the tendency of the latter to distortion. They were carefully turned to uniform sizes at the ends and the flange joints were made with a preparation called "Smooth On," which, however, did not entirely prevent leakage of the air pressure.

After the cylinders were concreted they were capped with ⅝-in. plates 40 in. square on which were seated sets of five 15-in. I-beams 4 ft. long parallel with the wall. These beams were bolted together with cast-iron separators and each set supported on their top flanges eight 4-in. I-beams 3 ft. long transverse to the wall. They were covered by a 36x⅝x36-in. bearing plate on which new brick work about 2½ ft. high was built up to engage the old wall, and was wedged against it as tightly as possible in the usual manner. The spaces between the 4-in. I-beams were irregular and included four of sufficient width to receive a pair of steel wedges made by diagonally splitting a 4x4-in. bar 3 ft. long. Each pair of wedges was driven up snug, but not sufficiently to exert much pressure against the top and bottom plates, the intention being to transfer the weight of the building through the 4-in. I-beams and the 15-in. girders to the cylinders without reference at present to the wedges. Later on if settlement should occur, the wedges are easily accessible and can be driven so as to take up any displacement in the superstructure.

The Mills Building and the United States Trust Co.'s Building on opposite sides of the new building, are both of very heavy construction with their footings on the sand at a depth of about 13 ft. below the Wall St. curb. Their heights are respectively twelve stories and ten stories, and the estimated weight carried by the underpinning cylinders is 30 tons per linear foot for each structure. Before the underpinning was commenced, photographs of the buildings were taken and a very careful survey and accurate levels were made by Mr. John Van Horn. The buildings were frequently inspected, and after the completion of the underpinning and of the excavation for the adjacent pneumatic caissons, it was discovered that the maximum settlement had been 3/16 in. for one building, and that no settlement at all was perceptible for the other building.

At the corner of the Mills Building, the foot of the main wall with an estimated load of 36 tons per linear foot, was penetrated by large arches, one of which concentrated the weight on the corner pier where about 10 ft. of the side wall was also supported, thus bringing a total load of nearly 500 tons on a single pier. The brickwork was extended by offset footings to a width of about 5 ft. on the masonry foundations built on sand at water level about 19 ft. above the general excavation of the new building where the load on the soil was estimated to about 6 tons per square foot.

Trust Company of America Building.

Special care was necessary in underpinning at this point, because the dimensions of the pier were so small that a recess cut in it large enough to admit the 3-ft. cylinder would weaken it dangerously, and it was feared that if not additionally supported the pier might be crippled and cause serious damage to the building. It was therefore determined to support it temporarily before making the underpinning recess, and to this end concrete footings about 10 ft. square and 3 ft. thick were built on the sand at about the level of the old footing and close to it on each side. A horizontal slot was cut in the face of the pier deep enough to receive two of three 24-in. I-beams about 35 ft. long that were seated on the new footings. Short transverse 4-in. I-beams were laid across their top flanges in the plane of the wall and distributed the load from three 12-in. I-beams 4 ft. long that were carefully wedged up against the bottom of the brickwork. The slot in the brickwork was wide enough to take full bearing on these three beams, but not wide enough to receive the outside 24-in. I-beams. The load from the 12-in. I-beams was therefore transmitted through the transverse I-beams and equally distributed among the three 24-in. girders, thus transferring a portion of the weight of the superstructure to the new outside footings and greatly diminishing the pressure of the soil in case of any settlement.

The outer edge of the old and new footings was adjacent to the end of one of the caissons for the new building, and the space between the latter and the wall of the Mills Building up to the top of the 12-in. I-beams was filled in solid with concrete enclosing the offset faces of the old and new footings. In this concrete were imbedded short lengths of inclined I-beams with their upper ends braced against the webs of the 12-in. I-beams so as to virtually make under the corner of the building a large new pier greatly extending the area of the original pier and so bonded together with the beams and girders that it must act as a unit and provide ample bearing for the load and reinforcement for the old pier when the latter was weakened by cutting the recess for the underpinning cylinder. This recess was made 4 ft. wide and 38 in. deep, so as to entirely receive the cylinder, and the latter was sunk in it without difficulty, and being carried down to the solid rock will prevent any settlement of the superstructure even if undermining should be caused by the caisson work adjoining. After the completion of this underpinning cylinder, the temporary concrete pier which had been built outside of the Mills Building was removed and the ends of the 24-in. I-beams resting on it were cut off with chisels and hack saws at the building line so as to clear the caisson afterwards sunk where the temporary pier had been.

After the final operations of underpinning, the wrecking of the old buildings at Nos. 37 to 43 was accomplished. When the old structures had been removed down to street level, the subcontractor for the wrecking was succeeded by the contractor for the new foundations, who established a steel traveler on the first floor and used it for the removal of the remainder of the old building. This floor was exceptionally strong and heavy and was carried by 15-in. I-beam girders that were ample to sustain the traveler.

The traveler was designed primarily to handle the caissons, the excavated materials and the building materials used in the construction of the foundation piers and was installed before the new work was commenced so that it could advantageously handle the heavy members, hoist the masonry and debris and deliver it to the carts in which it was removed, without constructing special falsework, installing separate derricks or providing inclined planes which, or their equivalent, would otherwise have been necessary.

The traveler was built entirely of steel and has a 29x29-ft. rectangular tower about 30 ft. high over all, mounted on six double flange wheels on a 24-ft. gauge track. It is symmetrical about the center transverse and longitudinal axes and has two longitudinal sills each composed of a pair of 15-in. channels 8 in. apart back to back through the webs of which the axles of the wheels pass. Four transverse sills, each made with a pair of 15-in. channels 11 in. apart back to back are seated on the top flanges of the longitudinal sills about 9½ ft. and 14 ft. from the center line. These sills project about 2 ft. beyond the longitudinal sills and are framed to 15-in. fascia channels, web-connected to them. Three intermediate 15-in. transverse channels are also seated on the longitudinal sills and with them support the 3-in. planks forming the floor of the traveler. At each corner of the traveler there are two vertical posts each of them about 4½ ft. from the corner of the platform, one post being seated at the extremity of the intermediate transverse sill and the other being seated on the outside transverse sill between the longitudinal sills.

The tops of the vertical posts are connected by horizontal struts, each made with a pair of 15-in. channels. At the intersection these struts and the posts are riveted to heavy horizontal connection plates with reinforcement bars in the lines of the diagonals. The outer ends of the reinforcement bars are bored to receive the gudgeons in the top of the derrick mast and the inner ends are bored for connections with 1½-in. square horizontal diagonal rods, thus providing a completely braced system uniting the members of the tower and the derricks. Each of the four main faces of the tower is X-braced with a pair of 2-in. diagonal rods with loop eyes and sleeve-nut connections.

There are four masts, one at each corner of the platform, with the upper ends bearing in the horizontal connection plates already described and with the lower ends seated on special girders across the corners of the floor platform. This arrangement offsets the mast far enough from the double corner post to allow the boom a full swing of 270 deg. and affords clearance for its connections. The masts, 24 ft. long, are built with pairs of 12-in., 30-lb. channels latticed, and the 50-ft., 8-ton booms are made with four angles latticed and tapered from the center to both ends. They are rigged with four-part steel cable topping lifts and two-part hoisting tackles. The hoisting line runs over a sheave in the end of the boom, through the hoist block and back to the boom, where it is made fast to a long forged link pivoted to the axle of the boom sheave which also receives a similar link engaging the shackle to which the topping lift is attached. The opposite block of the topping lift is similarly connected to the top of the mast with a shackle and a long forged link, thus avoiding bulky connections that require a large clearance and limit the angle of the boom at its extreme positions.

The weight of the traveler is about 20 tons, exclusive of the boilers and the four double-drum Lidgerwood engines which are protected by a light corrugated iron canopy. All of the principal members of the traveler are connected with pins or bolts and are match-marked so that it may be readily assembled or taken to pieces in the field, carried from one job to another or stored in the contractor's yards. This traveler, although generally corresponding to the wooden travelers previously used by the same contractors and illustrated in these columns, is much lighter than the former, can be more easily handled and more quickly asembled and is not as much injured by wear and tear.

Before the first floor girders were removed, a pile driver was placed on them and drove forty 40-ft. piles in the cellar bottom to support the falsework for the working platform and traveler used in the foundation work, and thus provided for the traveler track after the floor girders at first supporting it had been removed. The traveler removed all portions of the old structure below street level and loaded them on trucks in the street with minimum handling and obstruction of traffic. The foundations of the old buildings consisted of wide continuous longitudinal footings reaching across the full width of the lot in the planes of the main walls and of the intermediate columns. The footings were very massive and were extended so wide that there was only a clear space of about 1 ft. between those for the intermediate columns and those for the main walls, thus distributing the weight of the building over nearly the entire surface of the lot. The lower course of the footing was of stone masonry with large flat slabs so heavy that they had to be broken before they could be loaded on trucks. The fragments were so large that they were not acceptable at the New York dumps and had to be carried a long distance for disposal.

The floor of the boiler-room in the Wall St. Exchange Building is about 15 ft. lower than was the cellar floor in the adjacent old building and in order to provide additional room there, the adjacent wall caissons, instead of being carried up to a uniform height with the others, were cut off at this level and the floor extended over their tops. Therefore, in order to retain the earth under the floor of the adjacent building the face of the caisson was virtually carried up to the higher floor level by means of a brick retaining wall of remarkably massive construction. It was 16 ft. thick at the base, 15 ft. high and 40 ft. long, made with brick laid in cement mortar, and was so strong that great difficulty was found in demolishing it, and it was removed in masses, some of them as large as could be handled by the trucks. After the removal of the wall, the caissons of the new building were sealed with those of the Wall St. Exchange Building at the end of the wall and no further necessity remained for such a structure between the two buildings.

The wrecking of the old building was so slow that time was not taken at first to remove the whole of the old footings and they were taken out piecemeal as was found necessary to clear the successive new caissons.

The work here described was supervised by Mr. L. L. Brown, general superintendent, and Mr. G. R. Johnson, superintendent in charge for the Foundation Co. The old buildings were wrecked down to street level by Mr. Byron Green.

(To be continued.)

The Empire Dam in Colorado is an earth structure 5.85 miles long and about 40 ft. in maximum height.

Experience With Fine-Grain Percolating Filters for Sewage.

Some time ago Dr. George Reid gave some evidence before the Royal Commission on Sewage Disposal concerning the operation of a sewage filter at Hanley. It had two beds, one circular and the other rectangular, each of ¼ acre area. The filtering medium is broken saggers, the fireclay pots used in burning fine stoneware. This material was graded to different sizes in four sections for comparative purposes, as the primary object of the filter was to ascertain whether a single filtration of the effluent of a septic tank would yield a good effluent in the case of this particular sewage. The applied septic sewage was distributed by sprinking apparatus working at the rate of 240 gal. per square yard in 24 hours. Analyses extending over a period of 18 months showed that the best results were obtained from the sections of the filter having ⅛-in. particles and these effluents were of a very high standard of purity. As the Commisison, in view of the entire absence of suspended solids in the filter effluents, desired to have fuller information regarding what became of the solids—both organic and mineral—during the different stages of the treatment, Dr. Reid has since conducted further tests with special reference to that point, and the following statements are taken from his reports concerning them. He also tapped the ⅛-in. grade section of the rectangular filter at different depths, introducing four rectangular shallow trays with perforated covers, from which pipes were carried through the filter wall; and was thus able to collect effluents from 1 ft., 2 ft., 3 ft., and 4-5-ft. depths. In order that the results from the lower depths might not be affected by the presence of the trays above, the trays were placed obliquely, from above downwards, so that no tray had another in a vertical line above it.

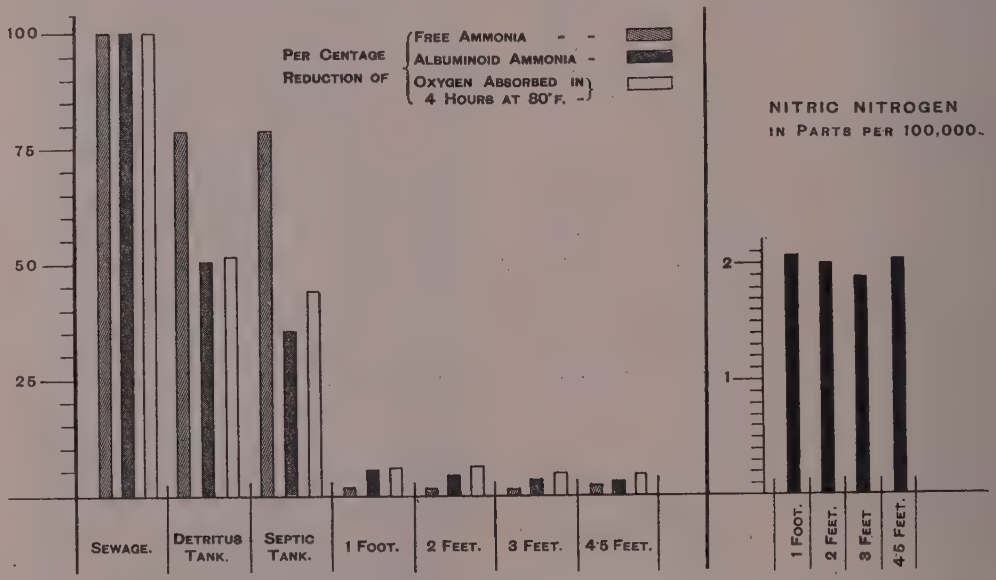


Diagram Showing Purification Attained at Different Depths of Filter.

The period covered by the analyses extended from July to December, 1905, inclusive, the filter at the end of that time having been in continuous use for a period of three years, dealing with the septic effluent at the rate of 240 gal. per superficial yard.

The accompanying diagram shows the percentage reduction in the free ammonia, albuminoid ammonia, and oxygen absorbed figures at different stages in the treatment, as well as the actual nitric nitrogen figure expressed in parts per 100,000.

With regard to the suspended solids, it will be noticed that a reduction of 73 per cent. is effected in the detritus tanks, and that a further reduction of 15 per cent. takes place in the septic tank, making a total reduction of 88 per cent., and resulting in an effluent being passed on to the filter containing 7.6 parts per 100,000, exactly one-half of which is mineral matter. This suspended matter is practically all retained in the top layer of the filter where the organic portion is liquefied. The mineral matter, however, must remain in the filter, and in time, no doubt, it will be found necessary to remove the filtering medium to a depth of a few inches for the purpose of washing it, but, so far, after over three years' constant working, no such necessity has arisen. As a matter of fact, if the total mineral suspended solids passing on to the filter during the three years were deposited in a uniform layer over the whole surface the depth of the coating would be less than 1¼ in.

The reduction of the free ammonia at a depth of 1 ft. is considered remarkable by Dr. Reid, especially considering the fact that the change has been effected in about 12 minutes—the time occupied by the sewage in passing downward through the first foot of filter. The rate of travel downwards of the sewage through the filter was found, as the result of several observations, to vary in accordance with the depth as follows:

From surface to 1 ft., 12 minutes; from 1 ft. to 2 ft., 12 minutes; from 2 ft. to 3 ft., 6 minutes; from 3 ft. to 4 ft. 6 in., 5 minutes; total 35 minutes. This is a slow rate of travel, compared with the rate in the case of large particle filters, which, in Dr. Reid's experience, in some cases, allow the sewage to pass through the entire depth of 4 to 5 ft. in about four minutes.

The free ammonia figure presents one other interesting feature. It will be noticed that the progressive reduction which takes place during the passage downwards through the first three feet is suddenly interrupted, a considerable increase in the amount being recorded at a depth of 4 ft. 6 in. Accidental error in analysis does not explain this, for the increase was invariably recorded, and, as a matter of fact, Dr. Reid verified the accuracy of the results by a second analysis in the case of the first few samples until it became quite obvious that no such explanation of the occurrence was feasible.

As regards the albuminoid ammonia figure, it will be seen that a highly satisfactory reduction is effected by filtration through 1 ft. only. In fact, this figure and the oxygen absorbed and nitric nitrogen figures considered together indicate a very high degree of purification which precludes the possibility of subsequent putrefactive change.

It will be seen that the reduction in the oxygen absorbed is, stage by stage, proportionate to the albuminoid ammonia reduction, and the rapidity of the change in this case also is equally marked.

With reference to the oxidized nitrogen, the figures are considered very startling by Dr. Reid, for, not only are they indicative of extremely healthy and active biological conditions, but, considered in relation to the other figures, they also demonstrate in the case of the sewage in question that the work of purification is practically completed within a few inches of the surface of the filter.

The objections almost invariably urged against a fine filtering medium are (1) the risk of clogging from suspended matter, and (2) the alleged defective æration. According to Dr. Reid's experience, clogging is more likely to occur with large than with fine-grade medium, owing to the fact that the suspended solids in the former case are not retained in the surface layers, where it would seem the active ærobic liquefying changes are effected, but are washed into the deeper layers where, in place of being liquefied, they accumulate and ultimately fill up the interstices. For this reason if Dr. Reid were compelled to make use of a large filtering medium, his inclination would be to adopt the suggestion which was the outcome of a long series of experiments at Leeds, and use such a large size as would allow of the suspended solids being washed through, and face the cost of providing means for their removal from the effluent afterwards.

With reference to the second objection—the difficulty of æration—Dr. Reid does not see why it should be advanced, in view of the incontrovertible fact that high nitrification is obtained by means of fine-medium filters. If it were desirable to use much finer medium than ⅛ in., there is no reason, from an æration point of view, why we should not do so. The only argument which weighs against the efficiency of a smaller grade medium than ⅛ in. is, that with fine material the suspended solids are apt to be retained on the actual surface, where rapid liquefaction cannot take place unless frequent raking and forking is resorted to.

The three essential factors in the final changes are time, air and organisms, and, given a sufficiency of air, the greater the number of organisms present the larger the amount of work done, provided the organic matter, both in solution and suspension, is brought into intimate contact with the organisms. The factor which governs the bacterial population is the area available for growth, and this may be increased by two methods, either by enlarging the cubic capacity of the filter or by subdividing the filtering medium. In the case in point, as indeed, in all cases in Staffordshire, the latter was the expedient adopted, and the sub-division was carried as far as it was thought possible to carry it without preventing the superficial penetration of the suspended solids into the interstices. In view of the results, it is needless to discuss whether the reduction in the size of particles resulted in an inadequate air supply.

The relative amount of carbonic acid in the air of the filter at different depths also shows the highly active oxidizing changes which take place in the superficial layers. A series of samples of air aspirated from different depths by means of iron tubes driven vertically into the body of the filter while in continuous use yielded the following mean results:

Carbonic Acid in Parts per 1,000.

1 ft.	2 ft.	3 ft.	4 ft.
19.5	21.5	20.0	20.0

An interesting fact bearing upon the æration of the filter was incidentally made apparent by the method of collecting the air at first adopted. The distributor passing backwards and forwards over the filter was found to interfere considerably with the collection of the samples, and, to obviate this, the apparatus was periodically stopped for varying periods during the operation. Owing, however, to extraordinary discrepancies in the results thus obtained, measures were taken to overcome this difficulty and enable the air to be collected without interrupting the regular flow of sewage on to the filter. The results, of which the figures just given are the means, were then found to be remarkably uniform, whereas in the case of the earlier samples the carbonic acid varied in amount according to the intervals which elapsed between the stopping of the distributor and the collection, short though these intervals were, from 2.8 to 26.1, showing how free was the current of air through the filter.

At the end of the observations the filter was opened and carefully examined throughout its depth, when it was found that the dark discoloration from deposit was confined to the surface, as was evident from the untarnished appearance of the light-colored filtering medium below the top 14 to 18 in. Also, the relative amount of organic solids in the interstices at different depths, ascertained by drying and igniting 10 grammes of the filter particles in each case, supports this contention, as the following figures show:

Percentage Loss on Ignition of Filter Particles at Different Depths.

6 in.	1 ft.	2 ft.	3 ft.	4 ft.
3.25	0.99	0.65	0.53	0.53

Apart from all theory, however, the fact has been established beyond all doubt, in Dr. Reid's mind, that, in the case of the sewage in question at any rate, the lower two or three feet of filter medium is absolutely unnecessary, and, so far as the cost of construction of the filter is concerned, the expenditure might be reduced by about one-half. Again, from the point of view of cost, another important consideration comes in. It frequently happens that the absence of two or three feet of available fall is the determining factor between a gravitation and pumping scheme, and in this respect the reduced depth of filter might lead to further economy, not only in capaital outlay, but in maintenance charges.

Dr. Reid has lately had an opportunity of applying the information recently acquired at Hanley in the case of a town in Somersetshire, where the sewage is much stronger and contains brewery refuse. A scheme, which had been based upon experiments previously conducted by the Surveyor of the District, was submitted to him for approval. The experimental filters, which had a depth of 4 ft. 6 in., were composed of clinker, broken to sizes varying from ¾ to ½ in., the distribution being by means of sprays. The results obtained were fairly satisfactory as regards nitrification, but the organic matter remaining unconverted was considerable, and the effluent, so far as appearance went, was a poor one. The engineer, however, had recommended a scheme on similar lines, but with 5 ft. 6 in. filters, believing that the extra depth would effect further and adequate purification.

In view of his Hanley experience, Dr. Reid recommended that the experiment should be continued, one-half of the area of the filter being altered as follows: The top 12 in. of clinker to be removed from one-half the area of the filter and replaced by ¼ in. to ⅛ in. granite chippings, and a collecting tray to be introduced at a depth of 3 ft. from the surface of this altered section. An opportunity was thus afforded of comparing the results obtained by the altered section at depths of 3 ft. and 4 ft. 6 in. with those from the undisturbed section at a depth of 4 ft. 6 in., under identical working conditions. Analyses of two sets of samples from the two sections of the filter gave the results in the accompanying table.

Results of Analysis of Effluents from Coarse and Fine Beds. Parts per 100,000.

Section	Unaltered	Altered	Altered
Depth	4½ ft.	4½ ft.	3 ft.
Solids in suspension	2.10	1.15	1.00
Free ammonia	0.710	0.250	0.067
Albuminoid ammonia	0.154	0.107	0.044
Oxygen absorbed in 4 hrs. at 80° F.	0.818	0.680	0.368
Nitric nitrogen	1.04	1.16	2.58

It will be seen that the improvement effected by apparently so trivial an alteration is remarkable. The improved quality of the effluents from the altered section of the filter at a depth of 3 ft. compared with those from the same section and the unaltered section at a depth of 4 ft. 6 in. is most striking.

A Great Steam Shovel Operation is planned by the Oliver Mining Co., which calls for stripping the overburden from 80 acres of ore at Coleraine, Minn. The average depth of the stripping will be about 80 ft., and it is estimated that 13,000,000 cu. yd. must be excavated. At Holman, not far away, the company is planning to undertake almost as much work of the same nature.

The Terms of the Panama Canal Contract.

The general features of the contract terms for the construction of the Panama Canal were briefly outlined in this journal last week, and the full text of Mr. Shonts' letter to the President on the subject was printed in the Current News Supplement. Inasmuch as bids will be considered from responsible companies of any nationality, and the work is of unusual nature and great magnitude, the more important details of the form of contract are given herewith. The proposals are invited specifically for "the completion of the construction upon the Isthmus of Panama of an 85-ft. lock level ship canal, having a minimum depth of 41 ft. and a minimum width at the bottom of 200 ft., between deep water in the Caribbean Sea and deep water in the Pacific Ocean, subject to the provisions stated in the draft of proposed contract annexed hereto." This definition of the intended work is in no wise changed in the "form of contract," and consequently any agreement under it will be legally void in case the summit level should be eventually fixed at any other elevation than 85 ft. Apparently few plans and specifications for the work have yet been prepared, for the official call for bids states that anything of this character now available "must be regarded as a general guide only and not as conclusively binding upon the Commission."

Bids are requested from any association of contractors legally competent to contract and having an unincumbered capital of $5,000,000. The tenders must be expressed in terms of a percentage of the estimated cost of construction, determined as explained hereafter, and must be delivered to the Commission before Dec. 12. Each tender must be accompanied by a certified check or satisfactory equivalent to the amount of $200,000, and a statement of the names of the surety or sureties who will go on the contractor's bond, if he is awarded the contract, in the sum of $3,000,000. Among the conditions in the bond is a provision that the surety shall not be discharged by reason of any failure of the Commission to give the contractor or surety any notice provided for under the proposed contract; a provision that the surety shall not be released by reason of any change in the terms of the contract; but that any such change shall only be a ground for reducing the liability of the surety under the contract to the extent to which the surety can show that the damages for which it is answerable have been enhanced thereby; and a provision that, in any suit on the bond, any award or assessment of damages by the chief engineer shall have the same effect against the surety as against the contractor.

Work to be Done.—The work to be done by the contractor shall be construction work proper, and shall consist of the following items:

1. Dredging, clearing and excavating the canal from the locks at either end of the canal to deep water.

2. Construction of the proposed dam at Gatun, and of the dam or dams at or near the Pacific end of the canal.

3. Construction of all locks and regulating works wherever located.

4. Dredging, clearing and excavating the canal from the dams at either end to the Culebra Cut.

5. Excavation and completion of the Culebra Cut with its revetments and approaches.

6. Removal and reconstruction of the Panama R. R. upon lines of relocation to be fixed by the chief engineer of the Commission.

7. Removal and transportation of all spoil of whatsoever character, whether by land or water, to such places, and its disposition in such manner, as may be designated by the chief engineer.

8. The quarrying, transportation and dressing of all stone required for masonry work, the manufacture and transportation on the Isthmus of concrete, the transportation and preparation on the Isthmus of timber, or other materials, except finished metallic parts, used in the proper execution of the above work and constituting a part of the completed canal.

All work shall be performed according to plans and specifications furnished by the chief engineer of the Commission; but these plans and specifications will be subject at any time to such alterations and changes as may be deemed advisable by the chief engineer or the Commission.

Plant and Facilities Furnished by the Commission.—The Commission agrees to furnish, free of cost to the contractor, plant, facilities and means as follows:

1. All locomotives, cars, steam shovels, drills, cranes, dredges, tugs, scows, dumps, rails, ties and track materials, electric light or power plants, and other machinery of a substantial character required to efficiently carry on the construction work; but not hand tools or machinery of a minor character usually carried in stock, save through its Department of Materials and Supplies as provided hereafter.

2. All raw materials put into the work, the machinery and appliances necessary for the operation and protection of the locks or other parts of the canal, but not the treatment, shaping, finishing, transportation upon the Isthmus, or incorporation into the work of such materials, nor the erection, or assembling of such machinery upon the Isthmus; cement; explosives; oil, coal, fuel, and at the election of the Commission, electricity, for the proper operation of any rolling or floating stock or other machinery used by the contractor in the performance of his work upon the Isthmus.

3. Construction tracks already built in a condition not less efficient than now existing; but additional construction tracks, including the relocation of those turned over to the contractor, must be built by the contractor.

4. Quarters for the proper housing of all necessary employees of the contractor; but the commission shall be allowed reasonable time for the construction of quarters additional to those now existing.

5. Warehouses for the storage of the contractor's tools and supplies.

6. Hospitals and hospital service for sick employees of the contractor.

7. Office buildings for the accommodation of the contractor's clerical and administrative force actually employed upon the Isthmus in connection with the construction of the canal.

8. Transportation of the contractor's employees, employees' families, and supplies over the Panama Railroad and its steamship lines at rates not greater than one-half the regular published tariff rates.

9. Free telegraph and telephone service upon the Isthmus necessary to the actual efficient discharge of the contractor's business.

10. Free trackage rights over the Panama Railroad Company's tracks for the work trains of the contractor, from canal cuttings to dump grounds, or docks when necessary, and return; and as a part of this obligation, the Commission will assume the cost of constructing such additional trackage, yards, or other facilities of the Panama Railroad as may be essential to the proper execution by the contractor of the work herein provided for, the amount and character of such work being always subject to the direction and approval of the chief engineer of the Commission.

11. Water for offices, engines, shovels, drills, dredges and other equipment needing water, from the water mains and tanks of the Commission.

12. Commissary stores which will be open to the contractor and his employees upon the same terms as to the Commission's own employees.

13. Mess-house privileges for contractor's employees equal to those at any time extended to the employees of the Commission. The contractor shall also have the privilege of taking over and operating upon his own account such mess houses, either directly or by contract with a third party, subject in all cases to the direction and approval of the chief engineer with respect to prices, privileges and general methods, and subject to the duty to furnish to the Commission's employees accommodations in all respects equal to those furnished to the contractor's own employees. Any profit or loss arising from the operation by the contractor of mess houses, shall be debited against or credited to the contractor.

The equipment which the Commission agrees to supply it will also maintain; and it will to that end operate and properly furnish and supply such machine and other shops as may be necessary, but this obligation shall not extend to the making of repairs which are ordinarily known as outside, yard or running repairs, which must be made by the contractor. The Commission, to the extent to which its machine shops may be adequate, will manufacture or repair for the contractor such minor machinery and tools as can be economically and conveniently manufactured or repaired at the said shops, charging the contractor actual cost plus 15 per cent. The judgment of the chief engineer of the Commission shall in all cases be controlling as to the extent and character of the above named facilities to be supplied by the commission.

Functions Reserved to the Commission.—The Commission will retain control of:

1. All engineering work in connection with the construction of the canal, including surveys and the general direction and control of the construction work to be done by the contractor with the right to fully inspect same.

2. Municipal engineering, including the construction of waterworks, sewers, roads and streets wherever located.

3. The Governmental and Police Department.

4. The Sanitary and Hospital Department.

5. The Commissary Department.

6. Mess houses, except in so far as the same may be taken over by the contractor as before stated, and their inspection in that event.

7. Quarters.

8. The construction and maintenance of buildings.

9. The operation of the Panama Railroad.

10. An Auditing Department, which shall have control over the books and accounts of the contractor, with authority to direct the manner in which all accounts relating to expenditure upon the canal construction by the contractor shall be kept and to which department the books and accounts of the contractor shall at all times be open.

11. A department of materials and supplies.

12. And generally, all powers, rights and privileges not herein specifically ceded to the contractor.

To Be Supplied By the Contractor.—1. The contractor shall furnish and employ all labor, foremen, superintendents, clerks, general office staff, and furnish all tools and machinery of a minor character necessary to efficiently operate the plant and carry out the work to be undertaken hereunder.

2. He shall make all repairs commonly known as outside repairs upon equipment and machinery employed by him.

3. He shall take over into his own employment all employees on the Isthmus upon the pay rolls of the Commission at the time he begins work, except such employees as the Commission may reserve to its own use. Employees

on what is known as the "gold list" taken over by the contractor under this article shall not be discharged, nor shall their salaries be reduced, except for cause, and then only when their discharge or salary reduction is approved by the chief engineer of the Commission.

4. He shall assume and carry out all contracts that may have been entered into by the Commission for the supply and employment of foreign or other labor, and shall execute in connection therewith such agreements or papers as may be required by the Commission.

He shall carry on the construction work, if required, during the night as well as during the day, and in such shifts as the chief engineer shall direct.

Payments.—Payments will be made to the contractor by the Commission on or about the fifteenth day of each month, covering the cost of the actual construction work done by the contractor or his sub-contractors upon the canal during the preceding calendar month, including labor cost, superintendence and clerical service on the Isthmus, transportation of workmen to the Isthmus, current purchases of tools and repairs made by the contractor, and the actual cost to the contractor of any materials put into the work; and excluding the cost of organization, administration, legal and general expenses of the contractor, interest, taxes, cable service, commissary purchases and the cost of running the mess houses, should the contractor take over the same, and all expenses to which he shall have been put by reason of his own negligence or inefficiency, or by reason of the supply of any unsound or imperfect materials rejected by the chief engineer, or any imperfect preparation or use of material, and all expenses not directly connected with the construction work which he may have incurred on his own account.

Upon the completion of the construction work upon the canal proper, and the final acceptance by the chief engineer or the Commission of the work done by the contractor, there will be paid to the contractor the agreed percentage upon the total estimated cost of construction as fixed by the engineering committee mentioned later, subject to the following conditions:

1. If the total actual cost of the construction estimated upon the basis prescribed above shall exceed the total estimated cost of construction as fixed by the engineering committee, there shall be deducted one-half per cent. from the percentage otherwise payable to the contractor for each $5,000,000, or half fractional part, by which the actual cost shall exceed the estimated cost. If the actual cost shall fall below the estimated cost, the contractor shall receive in addition to the stipulated percentage upon the estimate of the engineering committee one-third of the difference between such actual cost and the estimated cost. In no event shall the contractor receive a percentage upon any part of the actual cost exceeding the estimated cost, unless the estimated cost be increased as provided in the contract.

2. If the construction work upon the canal proper shall not be completed by the contractor within the time fixed by the engineering committee, the contractor shall forfeit as liquidated damages for each month that the work of construction shall exceed the estimated time for the construction, $100,000; if it shall be completed by him in less time, he shall be paid a premium of $100,000, in addition to all other compensation, for each month less than the estimated time in which he shall have completed it.

3. If, however, at the end of any year of the contractor's work, the cost of construction has not exceeded nor the rate fallen below the proportionate estimated cost or rate of construction, the Commission will pay to the contractor two-thirds of the agreed percentage upon the actual cost to such date; but if at any subsequent time the cost should exceed or the rate fall below the proper proportionate cost or rate, no further portion of the agreed percentage shall be paid until the arrears of cost and rate are made up.

4. No allowance shall be made the contractor for any interruption or suspension of the work unless due to an act of God or a public enemy, or an order of the Commission, or failure of the Commission to maintain or furnish plant or materials as agreed. Where the suspension of work is due to any of the last-mentioned causes, the time of suspension or interruption shall be added to the estimated time for the construction of the canal.

If any suspension of the work should be due to a default or order of the Commission, and such suspension should exceed one year, the contract may be treated as terminated by the contractor, who shall thereupon become entitled to receive such percentage as he may have earned upon the work actually done. At such time also an estimate shall be made by the chief engineer to ascertain whether the work to such time has proportionately exceeded or fallen behind the estimated cost and time; and proportionate profits or deductions shall be credited to or charged against the contractor accordingly.

All questions with reference to the percentage earned by or payable to the contractor, the deductions, premiums, or increase of the estimated period of construction, attributable to the above named causes, shall be determined by the chief engineer of the Commission, subject only to appeal to the chairman of the Commission.

Method of Estimating Cost and Time of Construction.—Within ten days from the execution of the contract, the contractor shall nominate two engineers of approved standing, who, together with three engineers to be nominated by the Commission within the same period of time, shall constitute an engineering committee. One of the three engineers nominated by the Commission shall be its chief engineer, who shall be the chairman of the engineering committtee. The committee thereupon, upon a consideration of all available data, and, if in their judgment it be deemed expedient, upon personal investigation of the work to be performed upon the Isthmus and of the conditions surrounding the same, shall estimate the total reasonable cost of completing the construction of the canal. In arriving at the estimated reasonable cost, the committee shall carefully take into account all the services to be performed and the means, facilities and materials to be supplied by the Commission in the construction of the canal, and shall exclude from the estimated cost their value and all interest charges of whatsoever character, cost of right of way and land damages, and all expenses incurred by the Commission in discharging the portion of the work reserved to it, and the organization, administration, legal, general and other expenses of the contractor, and shall make no allowance for losses or damages, legal or otherwise, attributable to the acts of himself or employees and subject to be sustained by him, nor any allowance for contingencies.

2. The engineering committee shall likewise, from similar data and investigations, estimate the reasonable time for the construction of the canal with the facilities afforded to the contractor under the terms of the contract. In fixing the time, they shall assume that the contractor will at all times employ, on a basis of eight hours a day for American labor and ten hours a day for foreign labor, a force of laborers and employees upon the actual work of construction or the superintendence thereof equal to the number that can be efficiently employed, having due regard to the progressive condition of the work, and that he will be supplied by the Commission with the plant before described necessary to fully employ his working forces.

3. The committee shall also submit alternative estimates of time and cost, based upon night work and two shifts a day of ten hours each for foreign and eight hours for American labor, and also upon continuous work with three shifts a day of eight hours each, and shall formulate a rule by which these estimates may be increased, or diminished, according to the time that the work may be carried on upon one or the other of these several bases.

4. If, at any future time, the plans and specifications for the construction of the canal, as submitted to the engineering committee, shall be materially altered in any respect, the committee, or a new committee formed in the same manner as the original committee, shall, upon notice of either the commission or contractor, promptly convene, and modify the original estimate as to the cost or time, or both, by adding to or taking therefrom the additional cost or time fairly attributable to the changes made in said plans and specifications.

Steel Ties for Street Railways in Cleveland.

In laying street tracks in sandy streets in Cleveland, the trench is puddled, causing the earth to settle 3 to 6 in., and occasionally developing considerable settlement over sewers. In clay and shale streets, the trench is opened deeper than will be needed for the ballast alone, and this extra depth is filled with sand which is afterward puddled. In clay it is necessary to lay a drain between the tracks, but it is unnecessary to drain sandy foundations unless they contain water.

On streets where the ties were tamped with material from the trench, in order to make a track for ballast cars, there has been a large amount of trouble of late years, ever since the track was eight years old. According to a paper read this week before the American Street and Interurban Railway Engineering Association, by Mr. C. H. Clark, engineer of maintenance of way of the Cleveland Electric Ry., this trouble has not occurred on tracks which had 4 in. of concrete placed on the beds and covered with 1 in. of sand before the ties were laid. Concrete was then placed between the ties and covered with a sand cushion for the pavement. This method has worked very well, but Mr. Clark does not consider it so satisfactory as tamping the concrete under and between the ties after the rail is laid.

Steel ties have been used with marked success on some of the Cleveland lines carrying the heaviest traffic. The first were made by the Lorain Steel Co., and were laid 10 ft. apart, alternating with wooden ties. The concrete was 8 in. thick under the steel ties and 4 in. under the wooden ties, and was carried down under each rail so as to form a beam 10 in. deep. Satisfaction has also attended the use during the last two years of steel ties of a trough section made by Seitz Bros., of Tiffin, and laid like the Lorain tie.

Of all steel ties, that made by the Carnegie Steel Co. is most acceptable to Mr. Clark. It is an I-beam section with a 4½-in. top flange, 8-in. bottom flange and a depth of 5½ in. The ties are spaced 6 ft. apart and the concrete is tamped 4 in. under the tie and 10 in. under the rail. Tie-rods are placed over each tie. This track costs $41.66 for ties and $85 for concrete per 100 lin. ft. Only the best 1:3:6 concrete should be used, for experience shows that poor concrete will result in early renewals. Special care must be taken in cross-bonding when steel ties are used, because corrosion is likely to occur where the current passes from the rails to the ties and tie-rods.

A Long English Transporter Bridge.

The town of Newport, in Monmouthshire, England, lies on both sides of the River Usk, and in order to accommodate the heavy traffic lately developed there without interrupting the navigation of large vessels, it was determined to replace the old stone arch bridge over the river at that point with a transporter bridge, parliamentary sanction of which was given in 1902. Contracts were awarded in 1904, and according to the London Engineer, the construction of the bridge has just been completed and the structure was opened for service this fall. This type of bridge was adopted on account of its economy over high-level bridges or subways with their long approaches, and because of the obstruction to navigation and the contraction of the channel due to swing bridges.

The bridge has a span of 645 ft., center to center of towers, and a clearance above high water of 177 ft. The total length between center of anchorages is 1,445 ft. and the total height above the roadway to the top of the towers is 242 ft., or 269 ft. above low-water level. Each tower is seated on four separate masonry piers about 79 ft. 9 in. apart on centers transversely, and 36 ft. apart longitudinally. It has a triangular longitudinal elevation and is composed of two transverse inclined bents intersecting at the top. Each bent is made with two inclined vertical trusses tapered from the middle to both ends. The trusses of each bent are connected by heavy longitudinal transverse girders at the level of the bridge floor and at the top and one intermediate point. Below the bridge floor there is no bracing between them, but the two bents are braced together longitudinally by horizontal struts and multiple intersection diagonals from top to bottom. The feet of the tower trusses have cast-steel shoes, pin-connected and anchored to the piers.

There are sixteen suspension cables, each having a cross sectional area of about 4¼ in. and provided with connections at both ends which engage pins through shoes on the tops of the towers. The same pins engage the ends of a corresponding number of anchorage cables secured at their lower ends to cast-steel shoes seated on inclined granite pedestals bearing against reinforced-concrete piers on pile foundations. The anchorage connections are made of pairs of long screw rod bolts in open chambers always accessible for inspection and adjustment. Besides the main cable there are a number of back stays at each tower carrying the ends of the connecting bridge and of its cantilevers beyond the towers.

The elevated span has two trusses of the triple intersection Pratt type about 13 ft. deep and 26 ft. apart on centers which are suspended on the main cables arranged in sets of four on each side of each truss. The construction of the truss is peculiar. The bottom chord is a plate girder with trolley rails on each side of the lower flange. The top flange is connected by U-shaped stirrups to pins in the feet of the vertical posts. These pins engage the adjustable connections of wire-rope diagonals. The vertical posts are made with pairs of channels and are pin-connected to the top chord. They have half holes only, at their ends to engage the top and bottom chord pins, an arrangement which is pointed out in the description of the bridge as "avoiding distortion and strain." The superstructure is proportioned for a wind pressure of 56 lb. per square foot on the windward and 28 lb. on the leaward exposed vertical sections.

The traveling frame from which the transporter platform is suspended is 104 ft. long over all and moves on 60 cast-steel wheels set in brackets having horizontal friction wheels to engage the edge of the girder flange. The suspended car is 33 ft. long and 40 ft. wide. It weighs about 16 tons, and with the 3-ton cables and the rolling platform, it makes a total dead load of about 51 tons on the overhead bridge. The car is operated by electricity at a maximum speed of 10 ft. per second, and has been tested with a working load of 120 tons.

An interesting feature of the construction was in the design and sinking of the eight piers carried by the pneumatic caisson process to marl at a depth of 68 ft. below low-water level or about 86 ft. below the river bank. Each pier was built with a steel cutting edge 20 ft. in diameter and about 40 in. high with a vertical exterior web and an inside upper ring with horizontal and inclined knee-braces. To the top of the cutting edge segmental steel rods and iron hoops were attached, making the reinforcement for a massive, dome-shaped concrete roof built over the working chamber and provided with a central air shaft. The outer edge of the dome was thoroughly bonded into the cylindrical face wall of stone masonry nearly 4 ft. thick, which was reinforced by vertical 1½-in. steel wire cables attached to the cutting edge.

The dome was made with concrete mixed one part Portland cement to three parts of fine broken stone and sand and was reinforced with about 75 lb. of steel per cubic yard. The exterior wall masonry was laid with cement mortar and was carried up simultaneously with the sinking of the caisson, to serve as a cofferdam. The outer surface was plastered smooth to diminish skin friction, and the inner surface was left as rough as possible to key with the filling made of concrete one part ground lime and four parts broken stone and sand. The working chamber was filled with 6:1 Portland cement concrete, and after it was set, the air lock was removed and the interior of the cofferdam was filled with 1:4 ground lime concrete. Each pier contained about 19,500 cu. ft. of masonry and concrete, and cost approximately $11,000. These are stated to have been the first concrete pneumatic caissons sunk in Great Britain.

Each anchorage contains about 35,800 cu. ft. of masonry, and has an effective weight of 13,000 tons to the maximum cable stress of 920 lb. Mr. M. F. Arnodin and Mr. R. H. Haines were the engineers of the bridge. Mr. Alfred Thorn was the contractor of the steel work, which was supplied by the Cleveland Bridge & Engineering Co., Ltd.; the cables were furnished by W. D. Brown & Co., Ltd., and the electrical apparatus by R. W. Blackwell, Ltd.

Letters to the Editor.

Flexure in Reinforced Concrete.

Sir: In the nomenclature adopted by your correspondent, Mr. J. L. Campbell, in his letter on the theory of flexure of reinforced concrete in your issue of Oct. 6, he lets $p =$ mean pressure per square inch in concrete above the neutral axis. Later, in applying numerical values, he uses 504 lb. as the extreme fiber stress in concrete and deduces $p = 336$ lb., which is two-thirds of the extreme fiber stress. The mean or average stress should be half of 504 lb. or 252 lb. The value given of 336 lb. is the stress at the centroid of compressive area, not the mean or average stress.

His assumption of a fixed position of the neutral axis at one-half the effective depth of the beam might lead to some very material errors in designing. The position of the neutral axis is a function of the percentage of steel and the ratio of the moduli of steel and concrete. For 1:2:4 concrete, such as used on the work described, the ratio assumed is usually 15. In order to bring the neutral axis to the center of the beam, the percentage of steel in terms of the area of concrete above the center of steel would be about 1.7, which is considerably more than is ordinarily used. With the neutral axis in this position, the ratio of stresses in the steel and the extreme fiber of the concrete would be equal to the ratio of the moduli. With 15 as this value and 504 lb. as the allowable stress in the extreme fiber of the concrete, the stress taken by the steel would be only 7,560 lb. per square inch, or if the steel was made to take a stress of 16,000 lb. the corresponding stress in the concrete would be 1,067 lb. With a given steel and a given concrete, if certain working stresses are desired, there is only one definite percentage of steel that will develop these stresses, and any variation from this percentage will give a variation in the actual stresses developed in the two materials.

Albany, N. Y., Oct. 8. R. Hopkins.

The Completion of the Philadelphia Filters.

Sir: I note in your issue of Sept. 29 a comment upon the completion of the filtration plant in this city in which you indicate that the local newspapers here would have you believe that had the "cry of fraud not been raised," filtered water would have been furnished by this time. I beg to state that had the work gone on as it was under the old contractors, the conditions of the finances, the scope of the work and the rate of progress indicate that filtered water would not have been furnished the main city before about 1909, and under the then plans, even with revolutionized methods it could not have been furnished as quickly as it will under present plans even though there was a wait of about eight months during which investigations of fraud and revision of plans took place.

The criminal suit against the contractors and officials for conspiracy has not yet been brought. The city has brought an equity suit for $5,000,000 against the conspirators. This suit has not yet gone to trial as the City Councils have not yet furnished the money to secure the attendance of necessary witnesses.

A suit was brought by the Commonwealth against the chief engineer on the charge of technical forgery. This suit was brought before the evidence of conspiracy had been unearthed. The accused was freed of this charge by order of the judge—the keystone of the Commonwealth's case having been previously knocked out by an erroneous ruling of the judge.

In the meantime the city has held up $114,000 due one of the minor contractors on a contract in which no fraud is charged, a charge of defrauding the city of $500,000 resting against them on a previous contract. They brought suit for the $114,000 which the city was holding as security against the frauds charged in the other contract. The lawyers in their wisdom state that the city cannot hold this money pending the trial of the fraud case, and it has therefore been paid to them. The principal contractor (against whom the suit for $5,000,000 has been postponed until his friends in Councils furnish the city with money to prosecute), has made the faint beginnings of a suit against the city which may be accounted for either on the grounds of the coming election or by a shrewd reasoning that if the case must be tried it had better be done immediately before the city officials are furnished with the necessary sinews of war.

From the tone of your editorial I infer that you get most of your news from a particular local paper which is absolutely unreliable. Read the others.

Very respectfully yours,

Cassius E. Gillette,
Philadelphia, Oct. 6. Chief Engineer.